

PHYSICAL AND CHEMICAL
E S S A Y S;

TRANSLATED FROM THE ORIGINAL LATIN OF
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KNIGHT OF THE ORDER OF WASA, PROFESSOR OF
CHEMISTRY AT UPSAL, &c. &c. &c.

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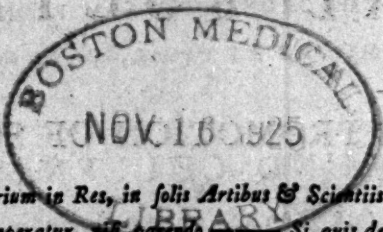
TO WHICH ARE ADDED
NOTES AND ILLUSTRATIONS,
BY THE TRANSLATOR.

V O L. II.

L O N D O N :

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M.DCC.LXXIV.



Hominis imperium in Res, in solis Artibus & Scientiis ponitur. Naturæ enim non imperatur, nisi parendo. Si quis depravationem Scientiarum & Artium ad molitiam & luxuriam & similia objecerit; id neminem moveat. Illud enim de omnibus mundanis bonis dici potest, Ingenio, Fortitudine, Viribus, Forma, Divitiis, Luce ipsa & reliquis. Recuperet modo genus humanum jus suum in Naturam, quod ei ex dotatione divina competit; & detur ei copia: usum vero recta ratio & sana religio gubernabit.

BACO DE VERULAMIO.

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TO THE
ILLUSTRIOUS
ROYAL SOCIETY
FOR THE PROMOTION OF SCIENCE
AND POLITE LITERATURE
AT BERLIN,
THIS VOLUME IS DEDICATED
BY THE AUTHOR,
WHO WAS CHOSEN A FELLOW
WHEN HE WAS PRESENT.

TO THE

ALLIANCE

ROYAL SOCIETY

FOR THE PROMOTION OF SCIENCE

AND POLITE LITERATURE

AT BRISTOL

THIS VOLUME IS DEDICATED

BY THE AUTHOR

WHO WAS CHOSEN A FELLOW

WHEN HE WAS PRESENT

AT BRISTOL

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Philosophia naturalis scripta est in maximo isto libro, qui continue nobis ante oculos jacet apertus (universum hoc ajo), sed nihil aut in eo legi, aut intelligi poterit, nisi prius addiscatur idioma, quo exaratum est. Characteres ejus sunt triangula, circuli & alia figura geometrica.
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Et alias invenio (gemmarum ardentium) differentias; unam, quæ purpura radiet, alteram, quæ Cocco; a sole excalescens aut digitorum attritu, paleas & chartarum fila ad se rapere.
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• *Multa sæculis tunc futuris, cum memoria nostri exoleverit, reservantur; veniet tempus, quo ista, quæ nunc latent, in lucem dies extrahet & longioris ævi diligentia. Rerum enim natura sacra sua non simul tradit; initiatos nos credimus, in vestibulo ejus hæremus; illa arcana non promiscue, non omnibus patent, reducta & interiori sacrario clausa sunt; involuta veritas in alto latet. SENECA.*

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*Ufus & impigræ simul experientia mentis
Paulatim docuit pedetentim progredientes.*

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Est quodam prodire tenuis, si non datur ultra. HORATIUS,

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*Quam pulchrum est, in principiis, in origine rerum
Defixisse oculos & nobile mentis acumen!
Pervolat huc Sapiens.*

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Ex omnimoda experientia, primum inventio causarum & axiomatum verorum elicienda est: & lucifera experimenta, non fructifera, querenda. Axiomata autem recte inventa & constituta Praxin non solum, sed confertim instruunt; & operum agmina ac turmas post se trahunt.

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*Nec manet ulla sui similis res; omnia migrant,
Omnia commutat Natura & vertere cogit. LUCRETIVS.*

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*Abdita quid prodest generosa vena metalli
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*Scientia a rebus occultis & ab ipsa natura absconditis ad usum
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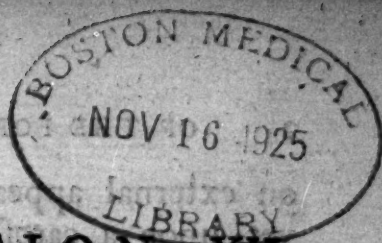
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DISSERTATION XII.
OF THE
FORMS OF CRYSTALS,
PARTICULARLY THOSE OF
THE SPATHACEOUS KIND.

§ 1. *Infinite Variety of the Forms of Crystals.*

CRYSTALS are bodies which, though destitute of organic structure, yet externally resemble geometrical figures, more or less regular. If we attend to the numerous collections of these, we shall be ready to conclude, that nature has effectually eluded our research by the infinite variety; for frequently bodies widely differing in their nature and properties resemble one another in figure; and, on the contrary, those which are exactly alike in properties put

on external appearances entirely different ; yet, upon a careful examination and comparison of this variety of figures, we shall find, that a great number of them, though their surfaces differ with respect to their angles and sides, may be derived from and referred to a very small number of simple figures.

Unless those figures, which are not improperly called primitive, be thoroughly investigated, the whole doctrine of crystallization will still continue to be, as it has been heretofore, a perfect chaos ; and those who undertake the description or methodical distribution of crystallized bodies, will inevitably lose their labour. For a series of years I have considered this intricate subject with much attention ; and I hope that my efforts have not been altogether void of success. I proceed to exhibit some specimens chiefly from the order of spathaceous crystals, and shall then endeavour to explain (as far as can be done upon a plane surface) how the spathaceous crystals, suitably agglutinated together, may form the great variety of dissimilar bodies which are to be found among crystals.

§ II. *Various Figures derived from the
spathaceous Form.*

The calcareous spar, as is well known, consists of a tessera, or oblique parallelopi-
ped ;

ped; all whose planes are rhombi of such a kind, that the obtuse angles are equal to $101\frac{1}{2}^{\circ}$, and the acute to $78\frac{1}{2}^{\circ}$. Let us now see how, by a proper accumulation of such similar parallelograms, crystals of the most opposite forms may be generated.

(A) Let A C E G O, fig. 1. tab. 1. represent a spathaceous nucleus, through whose opposite angles, D O, the axis H O passes: let us suppose, that contiguous rhombi are applied to this, above and below; and that these rhombi are equal, similar, and parallel to the subjacent planes of the nucleus; these, to avoid confusion in the figure, we shall only represent by the rhombi M P, M Q, and M T, which will be sufficient for those who are skilled in geometry and perspective.

By this method an hexaedral prism is generated, consisting of six equal and similar parallelograms, and terminating at both ends in three rhombi, which unite, and form a solid angle: this form of crystallization belongs to some of the calcareous tribe, but more particularly to schoerls; it is therefore called the schoerlaceous form.

(B) If the accumulation of the planes is stopped when the sides of the prism have acquired a rhomboidal nature, we shall have a dodecaedron included by rhombi: this is the usual form of garnet, when perfect.

(C) The garnetic form is easily changed
B 2 into

4. OF THE FORMS OF CRYSTALS.

into another, *viz.* into that in which the hyacinth often presents itself: this is effected by the regular application of equal and similar rhombi to each of the solid angles, which are composed of four planes, for the garnet has six such, when complete as to figure, and eight with three sides; let fig. 2. be consulted, where the dotted lines express the genesis of the prism more intelligibly than words can possibly do. In this operation the four rhombi are changed into an equal number of oblong hexagons: L H A B into L H h a b B, &c. &c. &c.

(D) Sometimes planes are applied, similar indeed to the fundamental planes, but decreasing according to a certain law: this decrease, whether owing, as is most probable, to a deficiency of matter, or to some other cause, must necessarily change the appearance of the terminating planes, and occasionally either augment or diminish their number. Let us now return to fig. 1.—suppose similar planes, but continually decreasing (M p, M q, M t), applied to the internal nucleus, these will ultimately end in an apex on both sides; so that, instead of a prism, we shall have a double pyramid, one tending upwards, the other downwards: at the surface the planes which meet form intersections or common bases, whose angles alternately tend upwards and downwards, as is shewn by G F E A C B G: this is the form of
of

of the calcareous crystals, which are called by the miners pig-tooth spars (*dentes suilli.*)

It is evident, that the axes of the pyramids are the longer, in proportion as the rhombi decrease more slowly; and the contrary.

If the decreasing series is stopped before the ultimate sides of the accumulated planes vanish, truncated apices will be generated; of which frequent examples occur.

In the calcareous pyramidal crystal just described, if the dorsal margins A H, B H, or F H, be cautiously struck, they break off into spathaceous tesserae; but this is not the case with the alternate margins C H, E H, and G H, which it is scarce possible to bring to that state; the reason is evident—in the former case the direction of the blow is parallel to the accumulation of the planes; whereas, in the latter, it meets the intersection of two planes:—this property also obtains in the lower pyramid, with this difference, however, which necessarily results from the very structure, namely, that the margin A I must produce a directly opposite effect from the margin A H; and the same is true of the rest, *mutatis mutandis.*

(E) Frequently, also, the fundamental planes themselves are imperfect; if, in this case, planes similar to them be added, forms of crystals must be generated more or less unlike the perfect form.—Examples of this

6 OF THE FORMS OF CRYSTALS.

are very numerous ; but in this place it will be sufficient briefly to explain a few.

Let A B C D E F G, fig. 3, represent the three rhombi which constitute the apex of a perfect schoerlaceous crystal ; let us now suppose the rhombus A G truncated in the direction of the line a b ; c G along c d ; and E G along e f. This being the case, the regular hexagonal figure of the prism A B C D E F is changed to an irregular one, a b B c d D e f F, consisting of nine unequal sides, whose apex is composed of three irregular pentagons, a b B G F, c d D c B, and e f F G D. I have now in my possession crystals of this form, both calcareous and schoerlaceous : to this class may be referred in general the rough turmalins, particularly those of Tyrol and Ceylon, of which we shall speak more expressly (a) hereafter.

It is obvious that pentagonal periphery a b B G F approaches more nearly to triangular, in proportion as the distance between a b and B F grows less ; the same is true of the rest : and when these distances become evanescent, a triagonal prism is formed, terminated by three triangles : if the cutting line a b, c d, e f, approach still nearer to the center G, and equally, the form still remains the same.

(F) The garnetic figure may be conceived as that of an hexaedral prism, terminated at

(a) De Terra Turmalini.

each

each end by three rhombi, meeting at the apex; and it may be composed of four equal spathaceous tesserae properly adapted; I have already mentioned its genesis (B); and its form is marked by the capital letters in fig. 4. If now, in the place of complete rhombi, we suppose accumulated in the same manner about its axis others, whose three external angles are truncated, or, which is the same thing, if the longitudinal margins of the prism be cut by planes parallel to the axis, a dodecaedron will arise, consisting of pentagons, which are indicated in fig. 4. by the small letters. Calcareous crystals of this kind sometimes occur, but they are generally so low, that *e* nearly coincides with *a*, *c* with *d*, &c.; so that the pentagon *a b c d e* becomes almost of a triangular figure, which is the figure attributed to them by some authors, who are ignorant of their true nature. Among the pyritacea we may sometimes observe instances of this variety complete.

Sometimes all the margins of the garnet are truncated, so that the number of including sides increases to twenty-four oblong hexagons; a change which may easily be derived from the positions already laid down. If the intersection *c d*, of the planes *e c* and *c r*, falls without the plane *B G*, a figure of a very different kind will be generated.

B 4

(G) The

(G) The hyacinthine figure (art. c) also sometimes labours under defects peculiar to itself. I shall mention one very remarkable variety which is met with in Hartz mines (*b*): there the crystals sometimes appear of a cruciform figure (A B C D E F G H I K L M, fig. 5.); the apex is at c, the figure A B C b c a is all in the same inclined plane; and that is the case with the other three homologous figures. Now, in order to investigate the primitive form, let the rhombi c N, c O, c P, and c Q be completed there, to an eye placed high in the axis, passing through c, will appear like squares situated in the subjacent plane, and we shall have the rudiments of this hyacinthine figure: for we may also conceive the granite form as a quadrangular prism, composed of four rhombi, touching one another only in their apices, and terminated at each end in four rhombi, meeting at the apex. This form, if a little protracted, or, what is the same thing, increased by applying to the apices similar and equal planes, becomes the hyacinthine form, and therefore may without impropriety be denominated the rudiment of it.

(H) If the added planes be similar to one another, but not similar to the fundamental planes, prodigious varieties will arise from hence; but I think it unnecessary at pre-

(*b*) F. Ehrhart, that unwearied observer of nature, sent me some of these; they are siliceous, not calcareous, though they have the appearance of the latter.

sent

sent to multiply examples, as what has been already said, if well understood, will be found abundantly sufficient to shew how, by a plain and simple method, many other figures may be reduced to the primitive forms.

(i) If any one imagines this doctrine to be purely geometrical and speculative, let him carefully examine the calcareous crystals, the loose texture of which, if cautiously and skilfully broken, will completely shew the internal structure (c): as to the harder crystals, endowed with the forms above mentioned, their parts cohere so strongly that they can scarcely be broken: the schoerls exhibit the spathaceous texture very plainly; and there is no doubt, but the garnets themselves are composed of lamellæ, as will readily appear to an attentive eye.

(k) Finally, we may add one peculiar observation concerning prismatic and hexagonal calcareous crystals, truncated perpendicularly; such sometimes occur, and they cannot derive their origin, in the manner above described, from the spathaceous particles, and by no other way can hexagonal prisms be generated: what then is the cause which destroys their apices?—I confess this to be a question which I am wholly unable

(c) My pupil, Dr. Gahn, first observed the central nucleus in pyramidal calcareous crystals.

to answer, unless we may assume an accumulation of planes, more and more deficient around the axis. We may from hence conclude, that something unusual occurs, as the truncated extremity is opaque, while the rest of the prism is transparent; but the upper hexagonal section is smooth and polished.

(L) We have seen then prisms of three, four, six, or nine sides, occasionally terminated by various apices: we have seen pyramidal, dodecaedral, cruciform, and other very different figures, generated from the same spathaceous form: besides, we shall observe, that these almost all occur, though the nature of the substance remains the same; and from thence we should be induced to put but little confidence in figure. If then this test, which undoubtedly is the most remarkable, so far as externals reach, is of so little use, of what value can the others be?—and with what success can we hope to form a system of mineralogy upon such distinctions? External criteria should certainly not be neglected, but he who trusts implicitly to them deceives himself: they may, to an experienced observer, yield some assistance, but can never serve to determine his assent.

§ III. *Structure of the most minute Parts.*

As so great a variety of forms may be produced by the spathaceous particles accumulated in different ways, it is probable that the differences of all crystals, with respect to externals, are owing to varieties in their mechanical elements. But here a question may properly be started,—whether the most minute molecules, and as it were the stamina, are naturally possessed of a determinate angular figure, or whether they first acquire it during crystallization?—In answer to this question I beg leave to mention some circumstances which occurred to me in the course of observation.

(A) If the small particles which separate from lime-water, when exposed to the air, be inspected with a microscope, they will be found spathaceous.

(B) The greater spathous tesserae, when accurately examined, are frequently found with striæ running diagonally (such as we shall hereafter find appear in saline crystals) which discover their internal structure.

(C) The cubes of common salt not only exhibit diagonal striæ, but frequently, upon each side, they shew squares parallel to the external surface, and gradually decreasing inwards (fig. 6); circumstances which shew the vestiges of their internal structure:
for

for every cube is composed of six quadrangular hollow pyramids, joined by their apices and external surface; each of these pyramids filled up others similar, but gradually decreasing, completes the form. By a due degree of evaporation it is no difficult matter to obtain these pyramids separate and distinct (as in fig. 7), or six of such, either hollow, or more or less solid, joined together round a center; this is the whole course of the operation, from beginning to end. All this is true of the salited vegetable alkali, commonly called sal digestivus sylvii; of the crystallized luna cornea (*d*); of the galena, or sulphurated lead, which is frequently to be generated at Fahlun in the heaps, roasted, as it is called *sub dio frigide*; quadrangular nitre too, which is of the spathous form, produces a similar congeries of pyramids, and these almost equally distinct with the preceding cubic crystals. A solution of alum, upon evaporation, does generally produce solid octaedra; but sometimes it also exhibits hollow pyramids, and upon such of them as are complete the junctures are very distinctly marked by conspicuous lines.

(D) Sometimes too other salts indicate the same construction by visible diagonals. The Rochelle salt forms an hexagonal prism; a section of which is shewn by fig. 8:

(*d*) C. H. Lommer, vom Hornertza.

when

when this kind of crystal is complete, the manner of arrangement among the internal particles is entirely unknown; but when the crystal is formed on the bottom of the vessel, the lower side cannot be perfect (fig. 9); and this parallelogram exhibits two diagonals distinctly (fig. 10.) This is also the case with the salt extracted from human urine, which is called microcosmic salt: besides, we should observe of the vertical triangles, that they are alternately transparent and opaque in pairs; which plainly points out a difference in the situation of their elements. I have also some crystals of nitre marked with diagonals, a circumstance which in others is generally concealed by the close connection of the particles.

(E) If we examine the hollow pyramid of common salt farther, we shall find it composed of four triangles, and each of these formed of threads parallel to the base; which threads, upon accurate examination, are found to be nothing more than series of small cubes: therefore, although the above circumstances seem plainly to point out the genesis of all crystals, from the union and cohesion of pyramids, whose sides, being different in form and magnitude, occasion the differences of forms; it yet remains uncertain whether the same internal structure takes place in those whose minuteness renders them totally invisible; and whether the primary stamina possess a determinate figure, or
are

are composed by the union of many shapeless particles. We have long known that the smallest concretions which are visible by the microscope, possess a determined figure;—but these are compounds: in the mean time, until this veil is in some measure at least removed, we cannot avoid comparing the process of crystallization with the congelation of water.

While the watery particles are concreting they exert a double tendency; by one of which they are formed into spiculæ, by the other these spiculæ are ranged in such a manner, with respect to one another, as to form angles of 60° : from hence the varieties observed in the particles of snow may be easily explained. The most simple figure is that where six equal radii diverge from a center, in the angle above-mentioned (fig. 11.) (e); the same angle will be preserved if the extremities of these be joined by right lines; which will also be the case, if each of the triangles, thus formed, be filled with right lines parallel to the base fig. 12. I have also seen hexagonal figures in snow;—but this by the bye.

Let us now suppose the particles which are employed in crystallization endowed with a tendency to form spiculæ, and these spiculæ with a tendency to arrange them-

(e) Mairan on Ice.

selves

selves at equal angles of inclination, and we shall have both the triangles and the pyramids composed of them, even although the primary stamina had not a determined figure; as the angles of inclination vary, the triangles and pyramids will also vary; and hence the different forms of crystals will be produced, which may to a certain degree be investigated geometrically, the angles being given.

We have hitherto supposed the existence of a double tendency, because the effect seems to be twofold; but both these effects may undoubtedly be owing to the same cause, namely, to a mutual attraction between the particles, which, according to various situations and peculiar figures of the atoms, at one time arranges them in the form of spiculæ, again connects the spiculæ already formed under equal angles of inclination.— I consider the mechanical elements as existing under determinate and peculiar figures, as, upon any other supposition, I find it impossible to assign a cause which should arrange different substances under different angles, and yet preserve these angles always constant in the same substance. But I do not wish to examine this conjecture any further, though it appears to me to be probable; because powdered resin, which must doubtless consist of particles of a great variety of forms, when sprinkled on an electrophorus

phorus is, by the electric fluid, formed into stars like those of snow (f).

§ IV. *In how many different Ways Crystals are generated.*

In order that the particles may be arranged, by the power of attraction, into determinate symmetrical forms, it is necessary that they should be at liberty, and very easily moveable. The best method of obtaining this end is to immerse them in some fluid of nearly the same specific gravity with themselves (g): this may be done in three different ways; 1. by water; 2. by a liquefying heat; 3. by a volatilizing heat.— These we shall consider in order.

(A) The most common method of crystallizing is by means of water, as it easily takes up saline matters, and, upon being sufficiently diminished by evaporation, yields them again in a concrete state; nay, until now it has been thought, that without this vehicle no crystals could be obtained.

But it is not only when actually dissolved in water that they require determinate forms; this, unless I am mistaken, is also the case when they are only sufficiently attenuated and mixed with it: for substances

(f) Lichtenberg first observed these resinous stars.

(g) Morveau *Digress. Academiques*.

not soluble in water will yet remain suspended in it, if by sufficient division they have acquired so great a surface, in proportion to their mass, as to approach the specific gravity of the fluid: now such particles doubtless possess attraction, they also possess the necessary degree of mobility; no reason therefore appears why they may not form crystals. And it seems highly probable that many of the earths which occur in the mineral kingdom symmetrical and of a regular form, have coalesced in this way.

A mechanical mixture and a true solution should be carefully distinguished, although they agree in weight. In the former case the particles, if collected and laid upon the bottom of the vessel, will remain there, unless diffused by agitation. A substance which is soluble, on the contrary, is totally and spontaneously distributed through the menstruum, even without any agitation; though the operation is certainly accelerated by agitation.

(B) Crystals may frequently be obtained by fusion and slow cooling: the matter of heat, in sufficient quantity, penetrating solid bodies which are not organic, softens and liquefies many of them; for when it penetrates and loosens the texture of the mass, it communicates mobility to each of them, so that upon slow refrigeration they are in a condition to obey the laws of that attraction

which tends to arrange them in a regular manner: thus sulphur, when melted and cooled, exhibits striæ, and at the same time acquires an electrical property: bismuth, zinc, and regulus of antimony, acquire a sort of tessellated appearance; nay, the last of these, when set to cool in a conical mold, becomes stellated, not only on the upper surface or basis of the mass, but along the whole axis. Glass, if melted and slowly cooled forms beautiful crystals (*b*). I have taken the scorix from furnaces where iron was fused, by the addition of a calcareous stone, and have sometimes found them of a regular prismatic figure. When crude iron is melted with lime, I have found complete octaedra in the scorix.

In large metallic masses, such especially as are difficult of fusion, the lower particles are generally so much pressed by the weight of the superior, that they shew no signs of crystallization, although on the upper surface of gold, silver, iron, and others, beautiful crystals are formed.

It will perhaps be thought extraordinary, by those who have not well weighed the matter, that I should refer the congelation of water to an operation of this sort; but we must consider, that it is by means of the matter of heat that water is fluid (*i*);
and

(*b*) Keir, Phil. Transf. for 1776.

(*i*) Phlogiston, the matter of heat, and fire, ought to be carefully distinguished: phlogiston, combined with pure
air

and that when this matter is diminished to a certain degree, it crystallizes and becomes ice. We have before (§ III. E.) compared congelation to crystallization : in this place we shall add another mark of resemblance.

Snow or ice, put into hot water, by its solution absorbs a quantity of heat, equal to 72° of our thermometer : the crystallized neutral salts produce the same effect, that is, they make the water colder, although the salts and the water had been kept in the same place for many days : for by dissolving they acquire a larger surface, and by that means are able to take up and retain a portion of the matter of heat ; which, being fixed, loses its power of heating, and consequently the thermometer sinks when put into the water. Hence it follows, on the other hand, that the heat should be increased during crystallization ; and this increment is easily observable when a large quantity concretes at once : in concreting the surface is diminished ; hence, so great a quantity of the matter of heat cannot be retained : what is superfluous, being set at liberty, recovers its property of heating, which it accordingly exerts, and that in proportion to its quantity.

air in a certain proportion, constitutes the matter of heat : fire is the action by which a proper body is deprived of phlogiston, by means of pure air, with such vehemence as to generate not only heat, but flame.

(c) Heat not only liquefies but volatilizes certain bodies: the material cause of heat penetrates the integrant parts, expands, attenuates, and, by its union with them, renders them so light, that they mount in the air: particles, after undergoing this process, when during cooling they are sufficiently at liberty, often obey the laws of attraction, and form crystals: to this class we may refer those which are condensed from the vapours of regulus of antimony, called the flores argentini. The galena, which is frequently interspersed among the copper ore, at Fahlun, from the heaps which are there roasted without heat, sends forth a vapour which condenses on the upper strata, forming hollow pyramids, which form the bases of the cubes of galena, entirely similar to those which compose common salt.

In the heaps of ore of arsenic which are exposed to the fire at Loefa, I have collected extremely beautiful white, yellow, and red crystals, partly tetraedral, partly octaedral: some of these exhibit hollow pyramids, whose sides consist of threads parallel to the base, precisely in the same manner as the crystals formed in the humid way (§ III. E.); so that through the whole process of crystallization, a mechanism every where the same, and analogous to crystallization seems to be employed: — nor let any one imagine, that these are to be considered as monstrous

monstrous productions, which throw no light upon the theory of crystallization; for these crystals, when complete, frequently shew the junctures of the pyramids, by very distinct lines; and, by proper address, we may be able to see the process through its various steps, from the first rudiments to the completion of the whole operation. If this structure, as is very probable, takes place in all, yet it will not contradict what has been already said concerning the spathous form, as elements of the spathous figure, properly applied, may readily form pyramids fit for this purpose.

A prism of any kind may be formed by the apices of proper pyramids, meeting together in proper number round the same point; and the apex may also be formed by a single pyramid, its vertical angle being turned outward: thus a four-sided prism, with similar apices, may arise in many ways: thus to the cube, indicated by the letters $A B C D$, fig. 15. let there be applied on each side the quadrangular pyramids $A B E$, and $D C F$; and we shall have the prism required. In this way common salt sometimes, though very seldom, acquires an apex (k). Let us suppose applied to one or both apices of the octaedron $A C B D$, fig. 16. a hollow pyramid $a d b$, but similar and equal to the fundamental figure; and the same

(k) Capeler, *Prod. Crystallographiæ*, t. iii. fig. 2.

figure will be produced : however, I must confess, that I have never seen alum prismatic, though often consisting of octaedra imperfectly joined, fig. 17. A four-sided pyramid may be composed of four tetraedra, and consequently a cube of 24; and it has also a double apex of 32. Thus we have a new construction, which undoubtedly sometimes takes place; for, as I have already said, arsenical crystals take sometimes the tetraedral, sometimes the octaedral form, which may therefore easily be mutually changed.

It is with less facility that hexagonal prisms are formed of such pyramids as have the same number of sides, unless tetraedral be admitted. In fig. 18 four hexagonal pyramids and six tetragonal meet; the first are easily resolved into six, and the latter into four tetraedra (fig. 19.); forty-eight of which consequently make up the whole mass, supposing this to be the method followed by nature. I have no doubt that this construction is probable, on many accounts, for it requires only the most simple elements, and such as are conformable to the figures of all crystals. That tetraedra, adapted to this purpose, have sometimes dissimilar and unequal sides, makes not against the supposition: but what is most to the purpose, is, that sometimes such tetraedra are employed without the smallest doubt. All these circumstances are of no small weight; but

but so long as no traces of tetraedra are to be found among the pyramids of common salt, the laws of sound reasoning forbid us to draw any general conclusion: it is better to pursue actual observations than fictions, however ingenious: better cautiously to examine the mysteries of nature, than hastily and presumptuously to decide. I am perfectly certain that nature does frequently employ pyramids in this operation: it remains for future experiments to determine whether this be always the case, &c. I have been intent upon the mechanism of the concretion during a very assiduous examination of salts. I have related the principal phenomena which appeared, and at the same time have interspersed various observations; wishing that more sagacious observers may hereafter completely discover the system of corpuscular attraction, which is particularly obvious, and as it were palpable, in crystallization.

§ v. *Whether Crystallization necessarily implies the Presence of a Salt.*

Some of the moderns, considering that many salts affect an angular form, and frequently one of a constant and permanent kind, supposed this property to belong exclusively to salts; and when they met with any bodies similarly figured, they attributed this figure to a salt which they supposed

concealed in that body :—what judgment we are to form of this opinion, will appear from the following considerations.

(A) As crystallization is the effect of attraction ; and as all other matters, as well as salts, are subject to the laws of that attraction, we are not authorized to consider the regular and symmetrical figure as peculiar to saline bodies, although the assumption of such figure be more readily and frequently exercised by them, as being soluble in water. But crystals are produced by such other methods as can sufficiently divide and disengage the integrant parts (§ IV. B and C.)

(B) Upon examining salts it will plainly appear, that those which are most simple, and possess the saline properties in the most eminent degree, coalesce with the greatest difficulty. The truth of this assertion is evinced by the mineral acids and the caustic alkali, which, when pure, and freed as much as possible from every heterogeneous matter, it is scarce possible to reduce to the form of crystals.

(C) The similarity of forms in crystals does not depend upon the acid ; for, to pass over many other examples, the prismatic and quadrangular nitre, which are formed by the same acid, yet constantly differ in figure :—neither is the base sufficient ; for the vegetable alkali, as well as the mineral, saturated with marine acid, generates cubic crystals. The external appearance therefore

fore depends upon the menstruum and the base jointly:—we are not, however, from thence to conclude that there is present a neutral or middle salt, whenever the figure of such a one is discoverable. Not the smallest particle of alum is found in lead or nickel united with nitrous acid, although both these compounds yield octaëdral crystals.

(D) A great variety is observed in crystals, though the matter remains the same: I have already shewn this to be the case with calcareous crystals (§ 11). In the family of the pyrites, cubes are sometimes found striated in a singular manner, so that the lines of one side are perpendicular to those which distinguish the four adjacent sides (fig 13); but among these are also found tetraedra, octaedra, dodecaedra, and icosaedra; so that in this case all the regular solids are found.

(E) Finally, a very great number of crystals are either totally destitute of any thing saline, or else possess it in such small quantity that no experiments hitherto tried have been able to discover the smallest sensible traces of it. I have in my possession hexangular prisms of mica, which are composed of parallel lamellæ; the elementary spiculæ of which are disposed in a singular manner (fig. 14): gems, granites, schoerls, and other earthy bodies, are frequently found figured, though analysis can discover nothing saline. The same is true of gold, silver, and the other native metals; as also gold, silver, lead,

lead, tin, bismuth, and zinc, united with mercury, of which all put on regular forms, according to the quantity of the mercury (1).

If we have recourse to the supposition of an hidden saline substance, which cannot be discovered by art, it will surely be unreasonable to attribute to such a principle so great a power as that of arranging the particles in the order necessary for crystallization; a cause beyond question unequal to the magnitude of the effect: for how is it possible that a saline matter, the presence of the smallest atom of which cannot be discovered by the most delicate tests, shall in pure water have yet power to effect the icy crystallization with such force as to overcome the most powerful obstacles? How can a saline matter, which by no test can be discovered, have power, in an amalgam of gold, to arrange the ponderous particles of both metals in a particular manner? What salt is able to form the stellated regulus of antimony? what the hexagonal lamellæ of mica?—These observations will suffice for those who wish to build their knowledge upon the solid basis of experiment—to those who indulge hypotheses, the experience of centuries will convey neither conviction nor information.

(1) *Mem. de Chimie*, par M. Sage.

DISSERTATION XIII.

OF

SILICEOUS EARTH.

§ I.

WE find it long since observed by Theophrastus the Eresian (*a*), that a most excellent glass might be formed of that species of stone which strikes fire with steel, and is called flint; and hence perhaps it was, that all stones which joined to alkaline salts can form a glass, were called vitrescible. There are some, indeed, who explain this denomination in another way, and consider it as indicating only the property of melting by means of fire without

(*a*) De Lapid. 84. So Pliny, "*Auctores sunt, in India & crystallo fracto fieri (vitrum) & ab id nullum compari Indico.*"

addition.

addition. But as vitrescible earths, when alone, are very refractory, the former account seems to be more probable.

In the present century those stones which had before been called vitrescible, were called siliceous by Mr. Pott, and after him by Mr. Cronstadt. The celebrated chemist of Berlin, above-mentioned, seems to have been the first who (in 1746) established the genuine criteria of these stones; at least he determined them more accurately than any person before his time, and, after astonishing labour, discovered their habits, in mixture with the various earths and salts (*b*). Stones which are so hard as to strike fire, are commonly called siliceous; but this property depends more upon the connection of the particles than the nature of matter itself.

Glauber (*c*), if I mistake not, was the first who gave a clear description of the liquor of flints; though J. B. Van Helmont, in speaking of glass, asserts that if it be made with too much alkali it deliquesces; and that, by means of an acid, it precipitates a quantity of siliceous earth equal to that which had been used in the making of the glass (*d*).

Siliceous earths have been but little examined with regard to their principles and composition. Geoffroy asserts, that by repeated calcination they may be resolved into absorbent earth (*e*). Neuman relates, that

(*b*) Gethogeogn.

(*d*) De Terra.

(*c*) Furn. pars 2.

(*e*) Mem. Par. 1764.

he obtained from them, by distillation, an oily empyreumatic substance, which made syrup of violets red, and, upon addition of concentrated vitriolic acid, diffused the smell of volatile spirit of salt (*f*): but Ludovici, upon distillation, obtained, as he relates, from a pound of siliceous earth, two drachms of an acid liquor with a sulphureous odour, and the residuum by elixation communicated a styptic taste to water, from which, by alkali of tartar, a tartar was precipitated (*g*). Carl also obtained an acid liquor of the same kind (*h*).

Others say that they have obtained it sublimed with sal ammoniac, of a variegated colour, together with a green liquor. Neuman (*i*) asserts, that he was able, by means of vegetable acids, to extract a portion of lime from mountain crystal, but not from quartz; that the acids acted more powerfully upon the crystals when calcined; that of one drachm of the softer flint 22 grains were dissolved by concentrated vitriolic acid, and by the diluted acid 20; by marine acid 15; by nitrous acid 16; by vinegar 10; but that from the harder flints which strike fire, nothing was extracted (*k*).

Glauber (*l*) imagines, that on distilling powdered quartz or flint with two or three

(*f*) Prælect. Chem.

(*g*) Eph. N. C. Dec. an. 6 & 7.

(*h*) Juncker Consp. Chem. t. i.

(*i*) L. c.

(*k*) L. c.

(*l*) L. c.

parts of alkali of tartar, it foams out of the retort, and diffuses an acid liquor like to marine acid in smell, but differing from it in taste, and other properties; this liquor he thinks is derived from the alkaline salt, though Stahl ascribes it to the siliceous matter.

Pott asserts, that the earth precipitated from liquor of flints (*m*) by acids, is perfectly soluble in them, and that with vitriolic acid it produces alum (*n*); this was afterwards assented to by Beaume (*o*), but is very justly denied by Cartheuser (*p*), Scheele (*q*), and others (*r*). The celebrated J. C. F. Meyer observed (*s*), that liquor of flints, dilated with a certain quantity of water, bore acids without precipitation: this is a remarkable phenomenon, which will be explained hereafter.

Finally, the celebrated Dr. Priestly, who is making attempts to resolve all bodies into air, having exposed siliceous powder, moistened with acid of nitre, to an intense heat, obtained, in an apparatus prepared for the purpose, first aerial acid, then nitrous air and common air, and lastly air of remarkable purity; and these he obtained in the

(*m*) Contra Ellerum.

(*n*) Lithog. p. 3. præf.

(*o*) Man. de Chémie.

(*p*) Miner. abh. theil.

(*q*) Act Stock. 1776.

(*r*) Diff. couronnée par la Soc. Montp.

(*s*) Beschäft. der Berl. Gesellsch.

same order several times, by moistening the mass afresh (t).

The illustrious Count de Buffon considers clay as flint minutely divided, and on the contrary flint as clay very much condensed; how justly, will appear from the sequel. We shall pass over the loose conjectures of authors concerning the origin of this earth; conjectures which are only built upon the places where it is found, its situation, or other circumstances often very trifling; and only observe, that pure siliceous earth is generated in the distillation of the mineral fluor with vitriolic acid; a subject which has been so ably handled by Mr. Scheele. How this genesis of siliceous earth is effected we shall enquire hereafter in its proper place.

§ II. *Criteria of Siliceous Earth.*

In order to avoid all future ambiguity, it is necessary to begin by defining what is understood by the term *siliceous earth*. It is that earth which is precipitated by acids from liquor of flints, and which, even though the acid be superabundant, remains undissolved. Clay is also dissolved by alkaline salts, and is also precipitated by acids; but is again taken up by the acid, if sufficient quantity be added. I shall therefore

(t) Experiments on Air.

pass

pass over the latter, and go on to mention some of the principal properties of the former earth, such as are often useful to distinguish it from others; but I shall only take notice of a few properties which may serve as criteria. The following are the most remarkable, and such as serve to distinguish it very easily from all others.

The siliceous earth is not acted upon in the usual way by any acid, that of the mineral fluor excepted.

But it may be dissolved in fixed alkalis, either by the dry or the humid way; and in the former case, with violent effervescence, runs into a glass which is so much the harder as the siliceous earth, by means of a due degree of heat, constitutes a larger proportion of the whole mass. With $\frac{1}{2}$ alkali a clear and very hard glass is obtained; but with double or triple the quantity, a vitrified mass, which attracting the moisture of the atmosphere, deliquesces spontaneously.

It cannot be fused when alone by the most violent ordinary fire, but is dissolved by the addition of borax, without effervescence; it is also taken up by the microcosmic salts, though far more slowly and sparingly.

§ III. *Its Habits with Acids.*

The earth newly precipitated from liquor of flints, when washed and still wet, cannot be dissolved in the common acids, such as vitriolic

vitriolic, nitrous, and marine, although in that state its surface is increased as much as possible; and although to each part of earth 1,000 of concentrated acid were added, and boiled for an hour, the siliceous mass, when afterwards collected and washed, remains of the same bulk as before, and the menstruum is not impregnated with the smallest particle.

This is strictly the case with regard to pure siliceous earth; but if three parts of alkaline salt be melted in a common crucible with one of quartz, the salt dissolves at the same time about 0,07 its own weight of the argillaceous matter of the vessel, which are precipitated by acids, and re-dissolved upon adding a sufficient quantity of the acid menstruum: but it is obvious that in this case the argillaceous clay is a foreign admixture, and by no means a constituent part of the liquor of flints. If the operation be performed in an iron vessel there will be no argillaceous earth obtained, however often the experiment be repeated. There is certainly a portion of clay, though extremely small, which is always found in quartz itself: but the siliceous earth precipitated from liquor of flints, and freed by an acid from all heterogeneous matter, though afterwards repeatedly fused with fixed alkali in an iron vessel, will not yield even the most minute portion of clay; these different cases should be well observed, lest we be led into an erro-

neous belief of the conversion of filiceous into argillaceous earth.

We shall hereafter (§ iv. c) see that filiceous earth may, by certain management, be dissolved in acids.

(B) The fluor acid is never got entirely free from filiceous earth; so that, being more or less loaded with it, it must of course be found less active. Here it is proper to observe, that such earth is called filiceous as is either collected in the recipient during the distillation of fluor acid, or is afterwards deposited by that acid: the reason of this denomination will appear hereafter (§ v).

In order to examine the solvent power of this acid, in the year 1772 some quartz very finely powdered was put into a bottle which contained $\frac{1}{8}$ of a kanne of the acid; the bottle was then slightly corked, and set by in a corner of the room; two years afterwards it was examined, and, the liquor having been poured out, there were found concreted at the bottom of the vessel (besides innumerable small prismatic spiculæ) thirteen crystals, of the size of small peas, but mostly of an irregular form; some of them resembled cubes whose angles were all truncated, such as are often found in cavities of flints. These filiceous crystals, the first perhaps that were ever produced by art, were indeed hard, but not comparable with quartz, except in essential properties, in which they perfectly agreed. Possibly the length of a century may be

be necessary for them to acquire by exsiccation a sufficient degree of hardness. The bottle itself, as far as the liquid had reached, was found covered on the inside with a very thin siliceous pellicle, which was scarcely visible, but separated on breaking the bottle; it was extremely pellucid, flexible, and exhibited the prismatic colours.

These phenomena shew that much siliceous matter is dissolved and suspended: whether any of the quartz was taken up is uncertain, but it appears probable that little or none was dissolved in this experiment, since, by the help of heat, during the distillation the acid had previously taken up so much siliceous earth, that upon slow evaporation it was unable to retain it: hence appears the origin of the crystals and the pellicle; and hence appears the cause which impedes the action of fluor acid upon flint; namely, that the acid obtained in the ordinary way is already saturated with it.

Flint dissolved in fluor acid is most completely precipitated by volatile alkali; and by this method it is found that one part of flint is contained in 600 of the acid so much diluted that its specific gravity is only 1,064. This precipitate possesses all the criteria of pure flint (§ 11.): but that which is precipitated by fixed alkali, either vegetable or mineral, does not exhibit a pure siliceous matter, but a triple salt of a peculiar kind, composed of siliceous earth, fluor

D 2

acid,

acid, and fixed alkali, which dissolves, tho' difficultly, in warm water (especially that which is made with vegetable alkali), but is easily decomposed by lime-water, and lets fall the mineral fluor regenerated; so that this precipitate must be well distinguished, and not confounded with that which is precipitated by volatile alkali.

§ IV. *Its Habits with alkaline Salts.*

In the humid way (by boiling) fixed alkaline salts attack the siliceous earth, but not unless it be very finely comminuted, and newly precipitated from liquor of flints. Alkali of tartar, spontaneously dissolved by attracting moisture from the atmosphere, by boiling takes up about one-sixth of its own weight; and the liquor, upon cooling, forms a jelly, although at first diluted with sixteen times its weight of water. This solution is effected by the caustic portion which is always present in this alkali, for when the alkali is aerated it rejects the earth; nay, upon the addition of aerial acid, even the caustic alkali deposits the earth.

The volatile alkali, even though caustic, has no effect in this way.

(B) In the dry way fixed alkalis attract siliceous earth, insomuch that one-half its weight of these salts melt with it into a glass transparent, hard, and firm; which is
not

not the case with any other earth yet known. During the conjunction a violent effervescence is observed; but if the vapour which ascends be collected, it is found to consist of nothing but water and aerial acid.

If the proportion of alkali be greater, a glass is obtained more soft and lax; and if it be increased to double or triple, the glass attracts the moisture of the air, and is resolved into a liquor, which (from the siliceous earth) is called liquor of flints.

(c) This liquor is precipitated by all acids, as the alkali unites to them more readily than to the siliceous earth, which (being thus deprived of its menstruum) falls to the bottom. The siliceous matter, thus precipitated, is of an exceeding loose and spongy texture, and is swelled by water so much that its bulk when wet exceeds its bulk when dry at least twelve times: nor does it contract more in the water, though suffered to rest in it a long time. Hence the liquor of flints may, by time and a quantity of precipitant properly adjusted, be easily converted into a jelly, especially if diluted with four or eight times its weight of water: for in that case the fluidity is so regulated that the precipitant can easily separate the siliceous particles, and the particles so separated can at once occupy the whole mass; but if an overproportion of water be used (for instance, twenty-four times the weight) in this case the liquor remains limpid, al-

though so much acid be added as is more than sufficient to saturate the alkali. This is a remarkable phenomenon, the rationale of which, if I mistake not, is the following : —

The siliceous particles are removed from each other very much by the diluting water ; or rather, being diffused through so large a mass, are more rare. Now by every diminution of bulk the surface is encreased, and, together with that, the contact of the surrounding fluid ; hence, although the siliceous earth, by its specific gravity, should fall to the bottom, yet in the present case it is not able to overcome the resistance occasioned by friction, for greater force is requisite to open the way downwards than is supplied by the difference of specific gravities : the siliceous molecules therefore remain suspended in the fluid at the same time invisible, both on account of their tenuity and their transparency : but if the bulk of the fluid be diminished by evaporation, especially by boiling, which at once diminishes its gravity and tenacity, the siliceous matter is separated.

Liquor of flints is also decomposed by too great a quantity of water ; for by this the efficacy of the alkaline menstruum is so much diminished, that it is no longer able to keep the siliceous matter dissolved, and it is also partly saturated with the aerial acid inherent in the water.

(D) It

(D) It may seem extraordinary, that fluor acid should precipitate liquor of flints, as this acid strongly attracts the siliceous earth; but it is to be observed, that it still more strongly attracts the alkali: besides, in this case, it is not a pure siliceous matter which is precipitated, but an earth, combined both with acid and alkali, as was before observed (§ III. B). But there is some difference in the two cases, for in this instance the acid and the alkali, both loaded with siliceous earth, meet one another: while, therefore, the acid is saturated with alkali, it alone deposits a quantity of siliceous matter, this deposition therefore may all be dissolved by moderate heat in a sufficient quantity of water; and when exposed to the flame by a blow-pipe, readily fuses, exhibiting a pellucid little sphere, which, upon losing its fluidity, grows opaque and white. The precipitate from liquor of flints by fluor acid has the same properties, but somewhat less solubility and disposition to liquefy, doubtless occasioned by a larger proportion of siliceous earth: both these saline precipitates contain the fluor acid, which is discharged upon the addition of the vitriolic, and the ordinary phenomena exhibited. To an inattentive observer it will appear, that in this case we have the fluor mineral accompanying the acid; but a more accurate examination will detect this error: for the residuum, after the distillation of fluor, always contains gypsum, some-

times mixed with alum and flint, whereas here nothing remains but vitriolated alkali, intermixed with flint. Hence we see how much caution and vigilance is necessary to prevent us from embracing error instead of truth.

(E) The aerial, which is the weakest of all acids, yet precipitates liquor of flints; and that quickly and copiously, if it be suddenly added, and in sufficient quantity; but it is not necessary to mix them, it is sufficient if liquor of flints be exposed to the atmosphere, either open or imperfectly shut, for then the subtile precipitant is attracted, and the fluid deposited very slowly, in proportion as the alkali is aerated.

§ v. *Siliceous Earth possesses somewhat of a saline Nature.*

The proof of this is not to be drawn from the crystalline figures which siliceous stones often assume (for this is a property not peculiar to salts) more convincing arguments may be drawn from its composition and its solubility.

(A) In order to understand the genesis of siliceous earth, as far as it has yet been possible to penetrate that mystery, let us attentively consider the distillation of fluor acid; the phenomena of this operation are entirely of a new species, and, to be well understood, require the greatest skill and attention.

Let

Let 100 parts of pulverized fluor be put into a glass retort, and through a tube 50 parts of highly concentrated vitriolic acid be poured in; immediately a sensible degree of heat is found to arise in the mass, and a vapour of a most penetrating odour is produced; let 100 parts of distilled water be kept in the recipient; let a gentle heat be applied, which is to be raised by degrees, until the bottom of the retort becomes at last red: during this time the body and neck of the retort are incruited by a white matter, and the surface of the water in the recipient is covered with a crust of the same colour. When the vessels cool let the white matter in the recipient be first collected, well washed and dried; — it is found to be equal to about one part and a half of the mass subjected to the distillation.

This is very light and spongy; not only insoluble in water, but in the strongest acids; very refractory in the fire when alone; with one half of fixed alkali it yields a transparent and strong glass, but with three times that quantity produces a saline mass, which deliquesces, and becomes liquor of flints: in a word, it exhibits all the criteria of a true and pure siliceous earth; and, on exposition to the focus of a burning mirror, agrees with that earth, as the celebrated Macquer experienced with a small portion of this siliceous powder, artificially prepared in the laboratory at Upsal.

Besides the siliceous earth above mentioned, which is chiefly formed in the recipient, a white pellicle adheres to the neck and body of the retort; this, upon examination, is found to be nothing but the mineral fluor, more or less deprived of phlogiston, enveloped even externally by its own acid, but containing little or nothing of siliceous earth: it therefore easily fuses, upon exposure to the blow-pipe, and, upon addition of vitriolic, the fluor acid is expelled.

If the distillation be performed with an equal, a double, or a still greater quantity of vitriolic acid, the same phenomena take place, but with greater vehemence; more of the fluor is volatilized; and it sometimes even passes over into the receiver: the glass is almost always corroded, and, if thin, perforated. The water in the receiver, which by the first method contains a pure fluor acid, is in the latter more or less mixed with the vitriolic. The elastic fluid, which is generated, and may be collected in mercury, does not proceed entirely from the fluor alone, but is also mixed, more or less, with something proceeding from phlogisticated vitriolic acid; so that a wrong judgment is formed of the whole elastic fluid, from that by which it is adulterated.

The mineral fluor, distilled in the same manner with four times its quantity of nitrous or marine acid, yields the same product;

duct ; but a smaller quantity of fluor is volatilized, less fluor acid is extricated, and less siliceous earth is produced : the water in the recipient, besides the fluor acid, always contains somewhat of the decomposing acid ; nay, the acids of the vegetable and animal kingdoms produce the same effect, but in a smaller degree. The siliceous earth is then generally found to be wanting in the receiver ; and from the weakness of the decomposing acid a smaller quantity of fluor acid is expelled, sometimes indeed so small, that the whole of the earth produced is dissolved, but it can again be separated by volatile alkali. According to the new table of attractions of the fluor acid it has a greater affinity with lime than the nitrous, marine, and other acids have ; and this is agreeable to experience ; but when heat is applied the more volatile, though it be the stronger acid, must yield to the more fixed : the fluor obstinately resists fire when alone, but by means of another acid a small degree of heat is sufficient to volatilize it. The mineral fluor, though often heated and extinguished in water, yet, when afterwards distilled with vitriolic acid, yields its acid in the usual way.

Most of these phenomena are easily understood, upon the supposition that the fluor acid, united with lime, constitutes the fluor itself ; that it is very volatile ; and that when expelled it elevates some of the fluor
to

to a certain height; and that this height is the greater in proportion as the expulsion of the acid is quicker. It has also been demonstrated before (§ III.) that when hot it attracts siliceous earth very powerfully; and this without doubt is the reason why glass, which is always partly composed of siliceous earth, is corroded.

The principal objections which in this business obscure the truth, and diminish the validity of our conclusions, though already mentioned, shall here be set in view together, as they throw several obstacles in the way of our research. These are, 1st, the immoderate quantity of vitriolic acid: if the fluor acid only be required, one-half the weight of the decomposing acid is sufficient; if a perfect decomposition of the fluor, there is need of four times the quantity, and in general we cannot err by the largeness of the proportion. 2d, By want of water in the receiver the glass vessels are more corroded, and the elastic vapour, which cannot be condensed into a liquid form without it, now for the most part bursts forth, being only confined by the portion of water which adheres to the vitriolic acid. Great obscurity arises from, 3d, confounding things that ought to be distinguished from each other: the volatilized fluor, the pure siliceous earth found chiefly in the receiver, the precipitates from the fluor acid by fixed or volatile alkali, are all substances that should be carefully

fully distinguished. In like manner the elastic fluid, elicited from the mineral fluor by a proper quantity of vitriolic acid, is very different from that obtained by the same acid phlogisticated.—But let us return to our proper business, for all the properties of fluor acid do not belong to the present enquiry, which only regards the siliceous earth. I thought it however necessary to mention such of them as lead directly to the end proposed.

The question then is, whence the siliceous earth which occurs in the operation is derived? whether it is extracted from the mineral fluor, and elevated by the fluor acid, or whether it is extricated from the glass vessel itself?—many circumstances, hereafter to be mentioned, are repugnant to each of these opinions; and the experiments which have hitherto been instituted rather seem to indicate that this substance is actually produced during the operation.

1st. That the siliceous earth does not owe its origin to the mineral fluor is easily shewn: for although this fluor sometimes contains siliceous earth, yet this does not always happen; and nevertheless as large a produce of that earth is had from that which is entirely destitute of siliceous matter as from that which contains it. The green earth of Garpenberg, for instance, is in general entirely free from siliceous earth, and therefore may be totally dissolved, either in
nitrous

nitrous or marine acid. This solution, upon the addition of caustic alkali, precipitates pure fluor, totally unchanged; but the mild alkali, by means of a double elective attraction, precipitates aerated lime: — on the addition of vitriolic acid gypsum is formed.

2d, As the glass is corroded by the vapour of the fluor acid, at first sight it appears not an improbable conjecture, that the siliceous earth which appears is produced from thence; but we must observe, that by employing a small quantity of fluor and a gentle fire, the siliceous earth may be obtained without any corrosion; besides, the corrosion bears no proportion to the quantity of siliceous earth.

3d, That the siliceous earth, dissolved or volatilized by the acid, passes over from the retort into the receiver, is an opinion contradicted by a variety of experiments; — if, in place of water, alcohol be put into the receiver, the acid is collected in it, but no siliceous powder, which, on the hypothesis of volatilization, ought to be found. Of this circumstance we shall speak more at large hereafter.

But the powder formed in the receiver, well washed, and distilled with vitriolic acid, is not elevated, much less does it pass over into the receiver, and it yields no fluor acid. Left it should be suspected that this is owing to a deficiency of the phlogiston necessary
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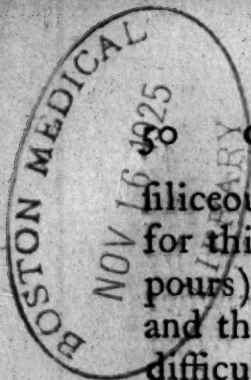
to volatilization, let a few drops of olive oil be added, and from hence, upon the application of heat, a white smoke will arise; and if the end of the retort's neck be plunged in water, a white squamous membrane is generated on the surface. This would at first appear a proof of the volatilization of siliceous earth, but upon examination the error is discovered; this membrane being found to be nothing more than a sebaceous matter discharged from the oil by means of the acid, in a state of coagulation, and carried up by the smoke; and the same kind of membrane is produced, if nothing be used but the oil and the acid. If the fluor acid be nothing more than a modification of the vitriolic (a question which must be decided by future experiments) the change produced in this case is a very singular one, and must be totally different from that occasioned in general by phlogiston: in the mean time it cannot with justice be denied, that the fluor acid is contained in the fluor itself; for if the fluor acid be mixed with lime-water, the mixture immediately becomes turbid, and a powder is deposited, which, washed and dried in a certain degree of heat, becomes phosphoric; distilled with vitriolic acid it yields fluor acid and siliceous earth, and agrees in all respects with the mineral fluor. On what pretext then can it be denied that the acid which was just now mixed with it is present in it? The mineral fluor is therefore lime saturated with

with fluor acid. Sometimes, indeed, there is present a little clay and flint; these, however, are not always found, but only casually, and they by no means constitute the essence of the substance. The greatest quantity that I have yet found was four grains of clay in an ounce of mineral fluor, that is $\frac{1}{150}$. There is also sometimes a small portion of marine acid, which has not yet been found to exceed five grains in an ounce of mineral fluor.

Upon considering these circumstances, which are not the result of a single experiment slightly considered, but of distillations frequently repeated and accurately examined, it seems necessary to have recourse to a new production, a thing which indeed should never be attempted but upon the best grounds.

In general we can no other way conceive the nature of fluid bodies than by considering them as congeries of solid particles, which are so minute that when combined with a certain quantity of heat, they acquire that degree of mobility which is sufficient to preserve a level surface; which level, if by any means disturbed, is immediately recovered. Now the primary aqueous elements, united while in a fluid state with fluor acid, scarcely contract a firm texture, but yield a dilute acid, a circumstance which takes place with respect to other acids; but upon the application of heat they put on the form of an elastic vapour, and
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in this state meeting with the vapour of the fluor acid, it is extremely probable that by their union they form the white powder above-mentioned: it is certain that when liquid they both offer a much smaller surface of contact than when in the state of vapour; and this difference in the latter case occasions a very close union, which in the former can scarce possibly take place, on account of the small surface of contact.—If mineral fluor be treated with highly concentrated vitriolic acid, unless there be water in the receiver, the elastic vapour can scarcely be condensed into a liquid form, but for the most part penetrates the luting, and corrodes the glass in a more than ordinary manner: by means of the water, which still adheres to the vitriolic acid, a small quantity of liquor will be formed; *viz.* as much as escapes being condensed into an earth. The acid vapour itself, collected in mercury, yields an elastic fluid not condensible by cold; water absorbs this acid fluid, but watery vapour coagulates it. Hence we may understand why pulverized mineral fluor, when exposed to a digesting heat in a close cucurbit, with twice its quantity of concentrated vitriolic acid, covers wet bodies, suspended over the mass, with a white powder, while dry bodies exposed in the same way do not contract a particle of powder; as also, why the fluor acid, often distilled with water, may be totally converted into



OF SILICEOUS EARTH.

siliceous earth. There is therefore necessary for this concretion (besides the hot acid vapours) water, also converted into vapour; and the coagulation is performed with great difficulty within the mass, but very easily at the surface, which, while fluid, is in a perpetual state of evaporation.

But whatever be the cause of this singular union (which is highly deserving of accurate examination) it is at least certain that the fluor acid makes a part of it: such a combination is very analogous to the neutral and middle salts, and therefore is not without reason considered as partaking of a saline nature, although scarcely soluble in water, in the same manner as gypsum, or as the mineral fluor (which consists of fluor acid saturated with lime, and is totally insoluble in water) is acknowledged to approach to the nature of middle earthy salts.

(B) Let us now see whether siliceous earth be totally insoluble in water. That certain waters contain siliceous earth is beyond a doubt; but it is probable that it rather remains suspended in them by means of the subtlety of its parts, than in virtue of a true solution.

It is known that water becomes the more capable of dissolving bodies, in proportion to its degree of heat; but in open vessels it is incapable of receiving a degree of heat greater than that of the boiling point, or 100° . Siliceous earth, exposed in water to a boiling

ing heat for ever so great a length of time, is scarce sensibly diminished, so that by this experiment it seems totally insoluble; but we cannot thence conclude that it is able to resist a greater heat. The efficacy of Papin's digester has shewn, that many bodies may be dissolved which totally resist boiling in open vessels: at the same time it must be confessed, that no one has yet tried siliceous earth in this way; so that we should be entirely ignorant what would be the event, had not nature herself spontaneously assisted our ignorance and sloth.

Thus, at Geyser in Iceland there springs up a hot water, which upon cooling deposits siliceous earth, and of this very matter has formed for itself a crater, in which columns of water of a stupendous bulk, after they have been thrown to the height of 90 feet and upwards, fall, and are again received. The heat of the water during the explosion cannot indeed be measured; but after it has risen and fallen through a stratum of air 90 feet thick, it raises the thermometer to 100° ; which evidently shews that the heat in the bowels of the earth must be vastly more intense; and this we shall cease to wonder at, when we consider that in this case the subterraneous fire acts upon the water in caverns closed up by very thick strata of stones, an apparatus far more effective than Papin's digester. The crater undoubtedly was at first formed,

and is daily strengthened, by siliceous earth, which quits the menstruum on its being cooled, falls down, and being in somewhat like a soft state, concretes (o).

From what has been said it abundantly appears, that siliceous earth is of a saline nature, but differs so much in degree of solubility, that our artificial limits oblige us to refer it to the earths.

§ VI. *Whether Siliceous Earth be a primitive Earth.*

Those earths are called primitive which cannot artificially be resolved into such as are more simple; derivative, those which are composed of two or more primitive earths intimately united: the question is then, to which of these classes the siliceous earth may with most propriety be referred?—If the question was, whether siliceous earth be altogether simple and homogeneous? the proper answer would be in the negative; for, upon considering the very probable circumstances above related, concerning the origin of this earth, it appears plainly to consist of two principles, namely, the fluor acid, and somewhat derived from the water. It cannot therefore be considered as simple and homogeneous; but inasmuch as we are ignorant of the true nature of the primary stamina of

(o) Vid. De Product. Vulcan.

water, and as it does not appear that any of the other primitive earths, such as lime, terra ponderosa, magnesia, or pure clay, are derived from the genuine substance of water, it appears that in mineralogy the siliceous earth may properly be considered as primitive, until by apt experiments, both analytic and synthetic, it be demonstrated that the base of this earth entirely agrees with some one of these above mentioned: when this is done, it may properly be referred to the derivatives, but not before; in the interim, naked conjectures and fallacious observations are not by any means to be confided in. It must be allowed that, to system builders, it will appear more simple to consider all earths as of the same species, with a very few modifications; but it should be remembered, that he who pretends *a priori* to judge of the most compound body in nature, ought first to be acquainted with the whole structure and œconomy of nature.

Some persons, observing that clay acquires by fire a flinty hardness, think that the principles of both are the same; an opinion which would be established beyond doubt, if siliceous earth, dissolved in fixed alkali, could, by means of the vitriolic acid, form alum, which has been attempted by certain moderns: but this hypothesis, when put to the test of experience, falls to the ground; for the pure clay is all converted into alum by vitriolic acid, and the siliceous

earth is not so much as dissolved by that menstruum (§ II and III. A).

Others, because common flints are generally found in chalky hills, imagine, that they originate from chalk, particularly depending upon misunderstood phenomena of gelatinous minerals: these phenomena are explained at large in the treatise on Volcanic Products. In the collection of the Academy, there is found an echinites exactly filled with siliceous earth, and surrounded with the same kind of substance; but the shell itself is still calcareous, and even of a spathaceous form. Now, in this case, since by hypothesis the calcareous earth has acquired a siliceous nature both internally and externally, how could the shell itself avoid the change? But the nature of the subject, which is still so much involved in darkness, from the want of a sufficient number of experiments, that we cannot certainly determine the origin of siliceous earth, forbids us to dwell longer upon this point.

§ VII. *In what Form Siliceous Earth occurs in the mineral Kingdom.*

The siliceous earth, such as it appears when precipitated from liquor of flints, and freed from all heterogeneous matter, is scarcely ever found, at least in the external strata of this globe; but is, like the other primitive earths, more or less mixed with other substances,

stances, and that as well mechanically (as is the case in common clay) as by a more intimate connection, and, as it were, solution; instances of which occur in serpentinum, asbestos, mica, schoerl, garnet, zeolith, and those stones which are called siliceous. So long as the siliceous nature prevails in the mass, they are not improperly so called, the denomination being taken from the prevalent ingredient: but here we must observe, that the nature of the compound does not always correspond with the quantity of the different ingredients; for the properties of certain simple earths are far more remarkable and intense than those of others. Thus a mass, in which pure clay makes no more than a fourth, nay even sometimes less, yet preserves the nature and character of clay; therefore it is that we call such mixtures siliceous which stand the criteria mentioned in § II; and, although the siliceous nature is sometimes more obscure, on account of the quantity and quality of heterogeneous matter, it is of no importance, provided the siliceous nature and properties prevail.

To this class we may, without reserve, refer quartz and mountain crystal, flints, properly so called, and jaspers; but more ambiguously petrosilices and felt-spar, as also zeoliths, schoerls, and lastly garnets, which are as it were intermediate between those and the gems; which are to be entirely excluded

ded from siliceous earths, as not only by their nature, but by the proportion of their primary principles, they challenge a place among the clays, as we shall see hereafter. Most of the last-mentioned stones abound in siliceous earths, and contain besides portions of calcareous and argillaceous earth, yet exhibit the siliceous properties notwithstanding;—the limits and design of the present Work prevents us from mentioning the specific differences.

DISSERTATION XIV.
OF THE
HYDROPHANOUS STONE.

§ 1. *Peculiar Property of the Hydrophanous Stone.*

BENEDICTUS CERUTUS relates, that he had seen with the greatest astonishment, in the possession of Chr. Furliger, an opake stone, which, upon lying in water, by degrees acquired transparency, and which, upon drying in the light, became again opake; for this reason he denominates it *lapis mutabilis*. Such stones were afterwards very scarce, and had the empty name of *oculus mundi* bestowed upon them. The reason of the former appellation is obvious; the latter is merely the sport of a warm

warm imagination. Dr. Hill has very properly called such stones as grow transparent in water *hydrophanous*.

An attentive consideration of the change produced will easily instruct us in the nature of this wonderful phenomenon. The transparency may be observed proceeding from the surface to the nucleus; and at the same time air bubbles continually arise from the surface of the stone, and float upon that of the water. Some assert, that the transparency begins at the center, and extends itself to the surface; but when that is the case it must be occasioned by some crack which admits the water at once to the center; all the hydrophani which I am in possession of, or have ever seen, have, conformably to natural expectation, grown first transparent at the surface.

The phenomena of clouds serve to shew that moist particles, copiously mixed with particles of air, prevent the transmission of light, and render the mass more or less opaque, although the particles of each, separately taken, are pellucid. The cause of this is to be sought for in the difference of refracting power; for by means of that the rays are turned from their original course at every particle, a circumstance which is very injurious to transparency. A common experiment will still more clearly elucidate this point:—the most transparent glass, when reduced to powder, becomes opaque, because

because the air, which now occupies the interstices, refracts the light much more weakly than the particles of glass do; but, upon pouring on water, which displaces the air, and differs less from the glass in its refracting power, a certain degree of transparency is restored. Setting down the specific gravity of water 1,000, we shall find that of air to be 0,001; and that of glass varying, according to its composition, from 1,791 to 3,380, which is the greatest: hence it appears, that the greatest difference between glass and water is 2,380, and the least is 0,791; the greatest difference between glass and air is 3,379, and the least is 1,790. From this calculation we may judge of the different quantities of refraction, and the consequent differences of transparency.

Let us now suppose a stone which agrees nearly with water in specific gravity, or at least is not more distant from it than glass; let us also suppose that its particles are transparent, but that it is uniformly perforated by invifible foramina, so that both air and water may be admitted, though not readily; we shall then have a stone, which, when well dried, remains opake, but, like the oculus mundi, grows pellucid in water. The superior effect which an alkaline lixivium produces in this case, depends on the superiority of its specific gravity.

Although

Although the causes of this phænomenon are thus physically explained, which always renders a phænomenon much less surprizing, yet to this effect three conditions, but rarely found united, are necessary; so that stones of this kind were very scarce, and valued at great and even immense prices. The extravagance of the price also prevented the examination of this substance; and our ignorance of its nature concealed from us the place where it was to be found; nay, so undecided were opinions concerning it, that the most acute examiners were doubtful whether it owed its origin to the mineral or to the animal kingdom: in the mean time the curious, both merchants and philosophers, were busily employed in search of it. The accounts transmitted to the Royal Academy of Sciences, Stockholm, were as follow:—

In 1770 the celebrated Quist, who had visited England, communicated some observations upon three specimens which he had seen in the British Museum; but as he was only permitted to examine them superficially, he could not determine their nature.

At the beginning of the year 1774 Mr. Poetzsch of Leipzig related to the Academy, that the year before a lapis mutabilis had been offered at the electoral collection for the price of 100 ducats; that this stone very much resembled a certain variety of the Eibenstock opal, which, upon trial, was also

also found to grow transparent in water: hence he concludes, that the lapis mutabilis is to be ranked in the family of the opals.

In 1776 Mr. Murray communicated to the academy a discovery which had been made three years before by Mr. Veltheim, superintendant of the mines in the Hartz, namely that the grey, green, and yellow hydrophanæ, are no other than thin crusts of the chalcedony of Ferro.

In 1777 Mr. M. T. Brunnich, professor at Copenhagen, in a memoir gave a confirmation of the chalcedony of Ferro's being the matrix of the hydrophanous stone: it is sufficient just to mention this; the other circumstances may be seen in the Act. Stockholm, an. 1777.

Having now mentioned this quality so highly prized, and shewn its existence in certain of the chalcedony and opal tribe, let us consider these stones a little more accurately; although it cannot be denied, that the same property may, and actually does, exist in some other species.

§ II: *The Opal and Chalcedony compared together.*

The opal and chalcedony agree with one another in many properties.

(A) The common colour of both is frequently milky; but the former is more pellucid

lucid than the latter; besides, the opal, viewed with refracted and reflected rays, exhibits different colours; but this property is not peculiar to it alone.

(B) The chalcedony is of greater specific gravity than the opal; but in this respect they do not differ much: the Eibenstock opal is from 1,958 to 2,075, and the chalcedony of different countries from 2,559 to 4,360.

(C) The opal does not possess sufficient hardness to strike fire with steel; the same is sometimes true of the chalcedony: so that, differing only in degree, they may, with respect to this property, be confounded.

(D) With regard to composition, they also agree, as I discovered by the following experiment:—I took 100 parts of chalcedony of Ferro, reduced to a very fine powder by elutriation, and formed it into a little ball, with three times as much mineral alkali, and a small quantity of water; after mixing them well together, I dried it, and exposed it cautiously to the fire in an iron vessel for an hour and a half; this operation requires the fire to be gradually raised, but not beyond a certain degree. This management is so difficult, that for once it succeeds the mass melts five times; for the more alkali is used, the more is the texture of the matter opened, that menstrua
7 may

may extract the soluble parts, but at the same time the more is its tendency to fusion increased; but the mass, when fused, must necessarily be loaded with iron, which renders an accurate separation of the principles very troublesome; and besides a portion adheres to the vessel, which is not easily got off: these inconveniences, therefore, must be carefully avoided; and whoever dislikes this scrupulous attention to the management of the fire, must diminish the quantity of salt, and reduce it to a fourth or sixth part of the chalcedony; by which means the end may be obtained, but more imperfectly. The ball, upon the application of a proper degree of heat, splits into a powder; this powder I collected and kept in marine acid in a digesting heat, until the residuum resisted the force of the acid: the insoluble powder, which was purely siliceous, when washed and dried, weighed 84 assay pounds; so that the undissolved part consisted of 16, which, precipitated and examined, appeared to be all argillaceous, mixed with some iron, but without the smallest appearance of any thing calcareous.

It is proper to observe, that the same chalcedony, without the previous preparation with alkali, yielded to the marine acid a portion of argillaceous earth, but four times less: it differs, therefore, from the common flint, which, treated in this way,
yields

yields scarce any clay, and is found mixed with calcareous earth, though in less proportion than the crystals of quartz.

I treated the Eibensstock opal in the same way, and it gave the same result as the chalcedony, whether crude or prepared with alkali: the argillaceous part was indeed a few pounds less; but I do not know that the difference is constant.

(F). From the above it appears plainly, I think, that opal is to be considered as a rarer and purer chalcedony, and the latter as a denser and coarser opal: that the opal is of a more spongy texture appears not only from the specific gravity, but also from this, that pieces of the opal often grow more transparent and more weighty in water.

§ III. *Of the Hydrophanous Flint.*

We have heretofore considered the opal and chalcedony; but these, when perfect, do not undergo the change in water of which we are treating, at least not in such a degree as to attract attention; but this property is sometimes found in the crusts with which they are covered: these we shall therefore proceed to examine more accurately.

(A) It may in general be said of those siliceous stones which resemble the common flint in breaking equally and smoothly,
that

that they are frequently found surrounded with a covering of coarser materials. I shall mention what appears probable concerning the origin of this crust:—evident marks frequently occur, which shew that these stones have gradually been indurated, and were originally a tenacious mass. Now, during this operation, the coarser particles, or those more imperfectly dissolved, while the bulk gradually diminished, were pushed to the surface by the more homogeneous matter, or sometimes towards the center, if any cavity be there to receive them; but as the mass grew more dense, the resistance also grew greater, and at length acquired so much power as to prevent the protrusion, it therefore obliged the protruded particles to settle in strata parallel to the surface; and these strata were at least distinguishable by colour and transparency from the rest of the mass: instances of this are seen in agates and chalcedonies. The external layers are generally more coarse, and have undoubtedly been protruded in the manner above-mentioned, while the mass was soft. On separating the layers, each internal is found of a more delicate texture than the adjacent external.

(B) The above-mentioned crusts must necessarily differ in texture, density, hardness, and gravity; it is therefore evident, that the three conditions necessary to the mutability required, cannot always be present in

these. Experience shews that the proper pieces, which are generally surrounded with those that are useless, cannot be distinguished by sight, by touch, or any external mark: those which, when applied to the tongue, do not shew any adhesive power, may be rejected; yet those which possess that power do not always grow transparent in water, although they admit it, two other conditions being equally necessary. Actual immersion for 24 hours will decide the question, as those which require longer time are not worthy of attention.

(c) Hitherto we have considered the crusts of siliceous stones in general; and although the involucra of all the varieties may perhaps sometimes yield the hydrophanous stone, yet experience shews that it is chiefly to be sought for among those of a loose texture, such as opals and chalcedonies.

(d) The crusts which grow transparent in water, on breaking appear dense and smooth, they stick to the tongue, do not strike fire with flint, are of a whitish yellow brown, nay sometimes blackish colour: their transparency varies according to circumstances; their specific gravity scarcely double that of water.

(e) As these stones are destitute of the hardness necessary to strike fire with steel (a property which is considered as the criterion of siliceous stones) some doubt may arise concerning the siliceous nature of the hydrophanous

hydrophanous crusts : I thought analysis the most proper means of solving this difficulty, and upon experiment found the same principles as before (§ II. E), which puts an end to all ambiguity. But it appears plainly that the greater or lesser degree of connection between the integrant parts affords a very insufficient and fallacious mark of discrimination ; and accordingly we find a great variety in this respect, even in the same tribe. We have already spoken of opals and chalcedonies (§ II. C) ; the same is true of cornelians, gems (*a*), &c. We have also in clay a very remarkable instance of the effect of different degrees of exsiccation ; for this substance, although when crude it attracts water strongly, and is softened and penetrated by it, yet by a certain degree of heat it is so condensed as to reject water ; and at length, by a very intense heat, it acquires a perfect flinty hardness. In this instance the very same matter exhibits very different degrees of cohesion among the particles ; and it is elsewhere demonstrated, that, even when hardened to the greatest degree, it yet retains an argillaceous nature ; we may therefore justly conclude, that the degree of hardness is not to be confided in.

(F) The value of the hydrophanous stone is estimated by its bulk, the quickness of the change, and the elegance of its colour.

(*a*) Vid. de Terra Gemmarum.

Of two equally penetrable the larger must necessarily grow transparent more slowly; but the effect may be somewhat increased by diminishing the thickness or perpendicular attitude, the length and breadth remaining the same. By this method many of them may be brought to grow transparent in a few seconds; and no doubt the wonder is much diminished, if the change does not take place under the eyes of the observer: besides, if several hours be requisite, neither can the process be properly examined, nor are the air bubbles expelled by the water sufficiently visible.

The colour is derived from iron; now, as that substance often differs both in quantity and quality, a considerable difference must arise, which generally varies between a yellow and a brown.

(G) That the opal gives admittance to water we have already observed; but the change is not very remarkable, because it is of itself semitransparent, but if naturally, by spontaneous calcination, or artificially, by a gentle heat, it contracts an opacity, we immediately get the hydrophanous stone. To make the opal opaque when dry, by means of fire, requires much caution; for if too much heat be applied, especially suddenly, it flies into small pieces.

(H) The change is accelerated by using the water hot, as it penetrates the foramina more readily, and the foramina themselves

are

are more open, on account of the heat; but whether it be hot or cold, the very purest water should always be used, otherwise the stone will gradually be obscured; for any water, though clear as crystal, leaves, upon evaporation to dryness, an earthy residuum. When the water then which has been admitted is gradually dissipated by evaporation, somewhat always remains behind; this, on account of its tenuity, for a long time does not injure the transparency, but if the operation be frequently repeated it may at length become visible; but this may be easily removed by acids, if, as is usually the case, it is of a calcareous nature. I am not ignorant that in this operation the colouring particles of tinged liquors are excluded, though the vehicles penetrate the stone; but it is equally true that alkaline lixivia penetrate, and of consequence calcareous and other solutions will also penetrate.

By concentrated vitriolic acid also the stone acquires transparency, but sometimes the colour is darkened by the acid remaining in the pores, and growing blackish; but this may be removed by an alkali. But the nitrous acid, highly dephlegmated, rather dephlogisticates than dissolves the iron of the stone, and occasionally produces various hues of yellow; but as acid menstrua are able to take up a little of the argillaceous earth as well as the iron (§ 11. E) there is no doubt but, if frequently used, they will

gradually change the texture of the stone. The water enters at the first trial more slowly than afterwards; it may therefore happen that a stone which at first scarcely admits water may, by lying a proper time in acids, have its foramina opened and dilated so as to admit it freely.

That the stone when transparent is more ponderous than when opaque, experience shews, and the fluid imbibed will easily explain the cause.

(1) We must not omit mentioning, that when the hydrophanous stone rendered transparent is exposed to the rays of the sun, or to an intense light, it frequently shews a spark or spot shining with peculiar lustre, which changes to different parts of the surface, according to the situation of the light. This property, which belongs to opals peculiarly, but not exclusively, is not difficult of explanation, as the hydrophanous stone is of the nature of opals; but is thus far imperfect, that when dry it is opaque, when wet however it grows transparent, and then acquires completely the properties of the opal. The property is of this nature:—let $L M N O$, tab. 2, represent the section of an opal, of a lenticular or ellipsoid form; let the parallel rays of light $l m l m$, &c. fall upon it, and a light will appear in the opposite quadrant above M ; in proportion as the incident rays are more oblique, the shining spot is more narrow and more brilliant;

liant; but the higher the luminous body rises, the larger and weaker is the shining spot. Let a light fall, by means of candles, on both right and left quadrant, and two opposite shining spots will appear, but weaker than the single. In open air, in the day-light, the half $L M N$ appears almost entirely overspread with a refracted light, but indefinite, not exhibiting any figure; yet when light is admitted into a chamber through a hole in the window-shutter, the shining spot represents the figure of the hole: it also represents the figure of the flame, and that in an erect situation, if l represents a lighted candle or the sun itself; therefore the adjacent rays, coming from the same points, are refracted within the stone, and form the figures of these points. When the incident rays are nearly parallel to the plane $N Q$, two or more curves of that kind called *caustic by refraction* diverge from M to the internal parts: those which arise from refraction from the opposite convex part $O L$ are seen within the stone, but those which are generated by refraction in the concave part $L M N$ are extended beyond the stone, in the plane $N Q$. In order to observe these phænomena distinctly, let the lighted candle l be placed at a foot distance from the perpendicular $R P$, passing through the eye at R , placed about half a foot higher than the flame; then let an ellipsoid opal be held upon the finger, or a card, at

the distance of an inch from the flame, and the caustic curves will appear: if the stone sinks ever so little in the line NS , parallel to RP , a refulgent point will appear within the mass at M , of the colour of the ray which passes through it: but at O , or the surface, a white spot appears; when it descends a little lower, in the same right line, the points change into flaming figures; at O a white and lesser one arising from reflexion; at M one coloured, and larger, which arises from refraction; these two, upon the further sinking of the stone, rise and meet together at L : by use we may easily learn to produce any of these varieties, unless the figure of the stone be improper, as upon this depends both the number and the differences of the curves. The colour of the figures which arise from refraction must necessarily be the same with that which the stone transmits; for it is known that opals seen with reflected and refracted light exhibit different colours: the mountain crystals, and other colourless pellucid stones, however suitable their form, do not exhibit these phenomena distinctly: certain vague collections of light may be seen, but a peculiar colour is necessary to distinguish the form of such appearances: this colour is here wanting, as all species of rays are transmitted.

The nature of our subject forbids the introduction of any thing more geometrical,
as

as what has been said is sufficient to explain the true nature and origin of these luminous points. We shall only add, that the stars which appear on the surfaces of spherical pellucid stones by a particular situation with respect to the light, are generally nothing more than a number of these caustic curves proceeding from the same point—to this perhaps may be referred the asteriæ of the ancients.

(κ) The crust of that stone which Born calls the *spatium piceum*, according to his observations, sometimes grows transparent in water, and is akin to the opals in its loose texture, its not striking fire with steel, in breaking smooth, and other external marks. Upon analysis I found it for the most part a pure siliceous earth, with a little clay; and an exceeding small portion of lime.

§ IV. *Of the Hydrophanous Steatite.*

Although this mutability is chiefly found in the siliceous stones of a looser texture, it must not be considered as peculiar to them alone. The conditions necessary for this purpose may also be found in the other tribes, as we shall here prove by an example.

The steatites vary much, both in colour and subtlety of parts, as is well known. In
this

this species also there sometimes occurs a structure of such a kind as to admit water; and as more than half the weight consists of siliceous particles, frequently pellucid, it may be easily understood how this may be rendered more transparent: but the hydrophanous steatites, being loaded with magnesia, seldom attains the same degree of transparency as those which consist entirely of siliceous earth, which are also more hard, tho' they yield in beauty and variety of colour to the others. Dr. Brückman mentions red, white, grey, and green steatites, possessed of this property; these he directs to be prepared first by boiling in an alkaline lixivium, and then in vinegar.

Experiments, if sufficiently multiplied, will doubtless discover hydrophanous stones in other species.

DISSERTATION XV.

OF THE

EARTH OF GEMS.

§ 1. *Various Opinions concerning the Earth of Gems.*

FROM the most remote ages, the transparency, the splendor, the colour, and hardness of gems have attracted the attention of mankind, so that, not only in the time of Theophrastus the Eresian, they were dignified by the name of precious stones; but in our days this product of the mineral kingdom is very dear, and not to be had but at an enormous price: but although it is very reasonable to admire, with Pliny, the perfection of their nature; yet, to the bulk of mankind, more solicitous about external glitter than internal perfection, they have rather

rather suggested the idea of making them subservient to vanity and luxury, than that of examining their real perfections. Their scarcity and extreme dearness for a very long time prevented them from being accurately examined, from whence it often happened that the wealthy paid dear for their ignorance, purchasing the spurious or artificial gems as genuine.

In the mean time mineralogists included them in their systems; but as they trusted too much partly to external appearances, partly to other fallacious marks, it was impossible but they must disagree about the arrangement; and certainly, so long as their analysis was not understood, no man could (unless accidentally) assign their true places, as long as it was unknown whether their earthy base was simple and primitive, or compound and derivative. Such as rank the gems among saline bodies, regard chiefly their figure; but these men do not consider that determinate forms by no means depend upon saline nature (although substances which are soluble in water are in a particular manner disposed to crystallization) inasmuch as metallic, inflammable, and earthy bodies, afford crystals, and those not unfrequently of a very beautiful kind; and in general the property of crystallizing seems to belong to every solid body, provided its particles be so subtilely divided and suspended (either in the dry or the humid

mid way) that while they are again concretizing they may be at liberty to obey their mutual attraction, and assume a symmetrical situation : in salts themselves the species of figure depends not upon the acid, nor yet upon the base which is united to it. The vegetable, as well as the mineral alkali, with marine acid assumes a cubic figure ; but the same acid, with volatile alkali, terra ponderosa, mercury, bismuth, cobalt, and other substances, assumes forms of a very different kind. If therefore in this case the acid has no effect, how will it act when it cannot be distinguished by any experiment, but its presence is inferred by bare conjecture ?—The same may be said of the base ; for each alkali, with different acids, yields dissimilar crystals. Alum and salited cobalt, when properly crystallized, yield octaedra, a figure which neither corresponds with the menstruum nor the base ; and what are we to think of the pyrites, which occasionally exhibit every one of the regular geometrical figures ?—but we have no need of multiplying examples, if that be known, which I think has been already sufficiently demonstrated, namely, that from a few primitive forms of the same substance, a great many derivatives, and those very dissimilar, may arise. These things being considered, I do not see with what propriety the diamond and the ruby are associated with alum, of which they do not shew the slightest vestige : but if,
after

after all, we are rather to trust to occult principles, on this foundation we may make alum of salited cobalt, and the other octaedral salts. On this hypothesis too the cubic diamond would be enumerated along with sea salt; and that which is an hexagonal prism, terminated at each end by three rhombi, among the schoerls.

Those who rank the gems among vitrescible stones, besides various negative criteria of lesser moment, maintain that they have a glossy appearance, and that, in fusion with fixed alkali, they run into a pellucid glass; the former of these circumstances is very fallacious, the latter indeed refers to a quality more essential. But we shall see hereafter what experiments shew on this head: hardness is in general but a very vague mark, as it often depends entirely upon the degree of exsiccation, the substance still remaining the same, as appears sufficiently in soft clay, when well burned. What some call vitrescent earths, others denominate siliceous; but names change not the nature of things, those being the best which are adapted to it.

In drawing up a system of mineralogy, if the figure, texture, hardness, colour, transparency, magnitude, and other external appearances, were every where and always sufficient to distinguish mineral bodies, this would perhaps (to beginners) be the most easy method, but it still would not be the best,

best, as these properties of bodies, which are applicable to human purposes, are derived from the nature of the constituent parts, and but rarely from the external appearance. No one is ignorant how fallacious superficial characters are, at least no one who has the least idea of modern mineralogy.—But such is the condition of man, that when he is led by the hope of success to attempt impossibilities, a long time passes before he returns to wisdom.

Among the most modern systems of mineralogy the most perfect by far is that of the illustrious Cronstedt, a system which he proposed with so much modesty as to conceal his name. In this all the substances are arranged according to their principles: if he sometimes considers those as simple which in reality are compound, it is not to be laid to his charge, as these errors proceeded not from a defect in his plan, but from the want of a sufficient number of experiments:—if he has not every where found out the right path, he always seeks it with candour, and describes it with precision. Treading in his steps, I have for many years laboured in the analysis of the mineral kingdom, in quest of the foundations for a system of natural history, more expressly adapted to the improvement of natural philosophy, and the advancement of public and private utility.

In various little essays I have, in a cursory manner, mentioned the conclusions drawn
from

from my experiments: in this place I am especially to treat of gems, in which class those crystals only are generally ranked which very much exceed the mountain crystals in hardness.

§ II. *Habitudes of the Gems examined by the Blow-Pipe.*

The tube which goldsmiths use for soldering, and which is employed by a few other artificers, is well adapted for experiments in mineralogy; its usefulness and convenience recommend it much, as I have at large mentioned in a treatise on that instrument. This is of the greatest use in the examination of gems, as the smallest pieces that can be taken up by a forceps (which in this case are sufficiently expensive) will serve for these experiments.

It is necessary at the very first to distinguish the diamond from the rest, as it is much harder than them, and also differs in other particulars.

Powdered diamond, exposed to the flame on a piece of charcoal, soon grows white, but scarcely undergoes a sensible change, as it is difficult to keep up the flame constantly for so long a time as is necessary to resolve it into vapour; while at the same time, for so long a continuance it is scarce possible to avoid some small inequality in the blowing, which will scatter it about; in
this

this respect other gems entirely agree with the diamond.

In order to obtain solutions of minerals by the *via sicca*, I employ chiefly three different kind of salts, namely, an acid, an alkaline, and a neutral. I am not acquainted with any acid which can endure the fire upon charcoal, except that of the microcosmic salt: this salt is neutral, but triple, containing both the volatile and mineral alkali. The phosphoric acid, saturated with volatile alkali, cannot be brought to crystallize; which yet always happens, upon the accession of a proper quantity of mineral alkali, and the triple salt which results from hence is commonly called microcosmic salt. Upon fusion on the charcoal, this sends forth its volatile alkali, so that the portion of acid which had been before saturated with it, being now set at liberty, is the better able to exert its effects upon other bodies. I make choice of the mineral alkali well depurated; the vegetable, on account of its deliquescence, is less proper. Of late I make use of borax, as being a salt nearly neutral, both the principles of which are fixed in the fire, and are much disposed to vitrification.

I have tried the effects of these salts upon the gems:—the microcosmic salt attacks them with difficulty, yet dissolves them; and with respect to this salt, there is a remarkable difference between the diamond

and all the other gems; for a small piece or a very subtile powder of it, immersed in a globule of this salt in fusion, during the fusion immediately floats upon the surface, at first sending forth slowly a few bubbles, which, upon continuing the operation, entirely cease. If the apex of the flame be kept constantly on the powder, it is gradually diminished, but is partly consumed by the fire, partly dissipated by the blast, and the residuum, which is very small, perhaps dissolved. The particles of the other gems enter into, and remain in the fused salt without effervescence; they wheel circularly about with great velocity, and are by degrees taken up, yielding water-coloured globules, unless when they are coloured, which, on vitrifying, they sometimes are, especially when hot.—These gems therefore are fixed to the salts by a more powerful attraction than the diamond, which on the contrary shews a sort of repulsion.

The mineral alkali, fused in a silver spoon [charcoal absorbs it] takes up the smallest particles of gems, and notwithstanding a long continued flame scarcely diminishes them; yet the emerald is resolved into a powder, but a refractory one. The diamond seems to elude its force altogether, as will appear from what follows.

Borax dissolves them almost in the same manner as microcosmic salt, but somewhat more quickly, and without any effervescence;

cence; but the diamond is more weakly attacked, so that after a long-continued fusion the globule adheres to the charcoal, and the powder lying on the surface is in the mean time dissipated.

The powdered diamond, before it is examined, must be depurated by aqua regia, for all that which is for sale abounds with heterogeneous matters, as we shall see hereafter (§ III. B): As the diamond exceeds all the rest in hardness, as it is by fire dissipated into smoke, and in all its habits differs from the rest, which in general agree with one another: these shall in the future be specifically comprehended under the name of gems.

The habits above described, especially those with the mineral alkali, distinguish the gems very completely from the mountain crystals, which are not only taken up by alkali, but also with a vehement ebullition or effervescence: those artificially made, which consist of an hyaline, or coloured glass, immediately betray themselves, by fusing without any addition.

Hence it appears that the diamond and the gems form genera as much distinct as quartz, garnet, schoerl, and many stones; yet it remains to be examined, whether the earthy base of each be primitive or derivative; and if the latter be the case, what simple elements, and in what proportion, constitute it?—These questions cannot be answered

but by the *via humida*, to which we shall therefore have recourse.

§ III. *Cautions to be observed, and Difficulties occurring in the Analysis of Gems.*

In this examination many obstacles occur, the chief of which we shall consider separately.

(A) The dearth of the matter not only persuades but obliges us to use small quantities; and in the operation we must be very cautious to avoid the loss or addition of any thing, as in an experiment on so small a quantity the least difference is of great consequence, though in a larger quantity it might be almost entirely neglected.

(B) Pulverizing the gems is attended with many inconveniences; they are possessed of such a degree of hardness that they are in this respect superior to all other bodies; when immersed, red hot, in cold water, they become scarcely more friable, though by this method the most solid mountain crystals are very easily comminuted. Struck by the hammer on an anvil the grains of mountain crystal split in general, but the fragments often fly about; and as to the diamond it frequently penetrates both the anvil and the hammer.—The diamond-powder which is for sale contains heterogeneous matters: from that which I got from the Baron Alstromer, and which had been lately

lately brought from Antwerp, aqua regia extracted 0,12, without the assistance of heat: the menstruum thus loaded was yellow: fixed alkali threw down a whitish powder, which, exposed alone to the blow-pipe, melted into an opaque globule of a metallic appearance; this effervesced with lime, with borax, and microcosmic salt; but the globule, with microcosmic salt, when loaded with a certain quantity, grew red on cooling, passing in a single instant from the most splendid reddish transparency to opacity. There is no doubt but that this foreign mixture is owing to the instruments made use of, for which reason the powdered diamond is sold at a smaller price than pieces of diamond so small that they are of no use but for pulverization.

The other gems are much more easily comminuted, and at length may be united with water; while the pure water is milky, it is to be carefully decanted, and fresh poured on repeatedly, until by degrees the whole mass has acquired such a degree of subtilty, that it can remain suspended, though remaining at rest for some minutes. The most extensive surface possible is necessary, that the menstrua may be able to loosen the close connection of the primitive principles; but as the agate is much inferior in hardness to the gems, something of the siliceous earth must necessarily be abraded, even by the most gentle triture, which

is mixed, and, although known as to its nature, nearly unknown as to quantity, unless by weighing the vessel exactly before and after, especially if it be convenient to make experiments upon small quantities only.

(c). It is not a little difficult to procure such vessels as are fit for these experiments in the dry way. The common crucibles have rough surfaces filled with little holes, which hide a quantity of the matter very considerable where experiments are made upon minute portions; and what is still worse, they consist of argillaceous and siliceous earth mixed, which must render our conclusion fallacious and uncertain, especially when fixed alkali is used. In order to discover the effect produced by this circumstance, I made the following experiment:—a small Hessian crucible, exactly balanced, weighed 1,585 assay pounds; into this I put 100 of dry salt of tartar, and exposed it for 37 minutes to a melting heat; but upon cooling I found no more than 1,645; so that 40 pounds had flown off, owing, no doubt, to the aerial acid and the moisture; the former adhering to the alkali, the latter both to the salt and the crucible. The fused pellucid mass at the bottom at first resembled a glass, but was by degrees obscured by attracting the watery vapours from the atmosphere: this I first washed with warm water, which, when decanted off, formed a jelly; when well washed,

washed, first with vitriolic acid, then with warm water, and dried, it weighed 12 lb. which, upon examination, appeared to be altogether siliceous. The solution precipitated by fixed alkali, gave 6 lb. of earth of alum; besides, the crucible was remarkably corroded, particularly about the surface of the fused mass. Hence the particles and fragments which were separated in the washing, when dried weighed 10 lb. but the crucible itself, well washed and dried, now weighed 1,594 lb. which is greater than its weight when new; therefore, as $12 + 6 + 10 = 28$, and $1,585 - 28 = 1,557$, and $1,594 - 1,557 = 37$, it is manifest, that during the fusion the fixed alkali had extracted 12 lb. of siliceous earth, that is nearly $\frac{1}{3}$ its own weight, and 6 of clay, or nearly $\frac{1}{6}$; and that besides the crucible retained 37 lb. of fixed alkali, which covered the bottom with a vitreous crust not at all soluble in water: these circumstances shew plainly, that we must not trust to the crucible in decomposing the several genera of earths by the dry way, as it will superadd heterogeneous matters, or at least change the proportions of the principles.

In the examination of quartz, I have for many years made use of the iron dishes which are described in the *Treatise de Terris Geoponicis*. It is well known, that the common rods of this metal are of a paral-

lelopiped form, two of whose opposite sides are broader than the other two; I made choice of forged iron of the best kind; the rod I had cut into pieces of an inch in length, and on each of the broader surfaces I hollowed out a segment of a sphere; in these cavities, when cleaned and polished, I put the mixtures with alkali, and by an iron cover prevented the falling in of ashes and coals. I also made trial of another metal, namely, platina precipitated from aqua regis by sal ammoniac, and afterwards fused by microcosmic salt, and then formed, by hammering, into a little cup; but the large pieces of regulus obtained this way were brittle, and none but those which were very small were so perfectly fused as to be malleable. The little cups made of this metal could therefore only contain a few grains; but if they can ever be obtained of a proper size, they will be in all respects the best, as being infusible by fire; and if at first they be sufficiently boiled in marine acid, the masses afterwards fused in them will not be adulterated with any iron; they may indeed be elixated by any acid menstruum, except aqua regis.

If the mineral earths are fused in iron dishes, by means of alkaline salts, a considerable quantity of the iron is mixed with them, which renders the separation of their primary principles extremely difficult; but by a proper regulation of the degree of fire
the

the desired end may be obtained without any inconvenience, as we shall hereafter see.

(D) In these experiments it is necessary to have the menstrua much purer than they are generally found. The vitriolic acid which is for sale is adulterated with a variety of heterogeneous matters, and among others sometimes with gypsum and vitriol, which occasions a considerable difference in enquiries such as ours. No other, therefore, is to be employed but such as has passed over from a low cucurbit by a gentle distillation.

The other acids too require to be depurated by a peculiar distillation, for it is particularly necessary that they be freed from all earthy or metallic mixture, as such must confound the quantity and quality of the principles which are explored by the analysis.

The common alkali of tartar is always adulterated with filiceous atoms, the weight of which frequently amounts to 0,02 ; these in the strong acids immediately are separated, but being united with the alkali, remain in the watery solution until the menstruum has attracted aerial acid from the atmosphere, which proceeds very slowly ; for this reason, in experiments which require much accuracy, I use no other alkali than the mineral well depurated, or the vegetable extracted by distilled water from cream of tartar

tartar in a well-burned glass vessel, which manifests no signs of siliceous earth.

§ IV. *Power of Acids in decomposing the Gems.*

There are only yet discovered five species of earths, which are so simple that they cannot, by any means hitherto known, be resolved into more simple ones, nor be transmuted one into the other; these are therefore called primitive earths, and that with justice, until new experiments evince the contrary:—these are terra ponderosa, lime, magnesia, argillaceous and siliceous earth. It cannot be denied that it is not altogether without probability some imagine that the number of these earths should be diminished, considering them all as modifications of one; but in the explanation of nature, we must not so far indulge conjecture, as to suffer the vain phantasms of imagination to prevail over phenomena confirmed by constant experience, and not impeached by a single experiment, when made with accuracy. Four of the above-mentioned earths are soluble in certain acids; the fifth alone rejects all acids, except that of the mineral fluor. If, therefore, some of these, in greater or less number, be united into one mass, chemistry is able to separate them all by the use of appropriated menstrua: enlarging the surface of contact assists the

the action of the menstruum very much, the earth must therefore be reduced to a very subtile powder. Sometimes, however, mechanical division is not sufficient, and the operation must be performed chymically, which, in the present instance, is done in the dry way, by means of an alkaline salt, which by attacking the siliceous earth loosens the connection of the principles—to what degree the use of mechanical pulverization alone may be carried, we shall soon see.

(A) Vitriolic acid did not attack the diamond in any way in which I have hitherto employed it; but I must confess, that I made use only of very small portions: I chose the smallest fragments of the thinnest lamellæ, being very reasonably distrustful of the powder which is for sale. A double weight of vitriolic acid, highly concentrated, added to a very subtile powder of the other gems, and afterwards discharged by boiling to dryness, operates very powerfully; for the residuum, elixated with warm water, yields not only a metallic colouring substance, but a small portion of lime: the metallic part, precipitated by a phlogisticated alkaline lixivium, yields a beautiful Prussian blue; so that from hence it clearly appears, that the red colour of the ruby, as well as the blue of the sapphire, the yellow of the topaz, the tawny of the hyacinth, and the green of the emerald, is to be attributed to iron;

iron; the quantity of which I determined by that of the blue precipitate. As I have elsewhere (*b*) demonstrated, that six parts of the Prussian blue are obtained from one of the dissolved iron, I precipitated the calcareous matters with an alkali, and it was found so pure, that with vitriolic acid it did not shew the smallest traces of argillaceous earth, except in the decomposition of the sapphire. Below are found the quantities extracted from 100 assay pounds, expressed in hundredth parts, or single pounds.

	Aerated lime.	Iron.
The ruby, red - - oriental	9	— 10
sapphire, blue - oriental	7	— 2
topaz, yellow - Saxon	8	— 6
hyacinth, tawny - oriental	20	— 13
emerald, green - oriental	8½	— 4

By this method all the calcareous earth and iron are extracted, as will appear hereafter.

(B) Concentrated nitrous acid, by digestion and decoction, yielded nearly the same result; I used eight times the quantity of this menstruum, continued the digestion for two days, and the boiling for an hour; I cautiously decanted off the clear liquor, and poured on again the same quantity of menstruum, digested, and then boiled it: this

(*b*) De Min. Doc. hum.

operation I repeated twice more, and then stopped, as the last liquor contained very little dissolved matter.

These liquors, collected and precipitated, gave nearly the same result as mentioned in A, at least with regard to the lime; and in the iron the difference never exceeded 0,02. The nitrous acid, especially when assisted by heat, dephlogisticates the iron, and in that case takes it up with great difficulty: hence too, in this experiment, the iron was mixed with a little ochre.

The diamond rejects this menstruum as well as the former.

(c) I employed the concentrated marine, as well as nitrous acid; and with the same success, except that it extracted the iron better than even vitriolic acid, but the difference did not exceed 0,01.

We see, therefore, that from the gems properly so called a small quantity of lime and iron may be extracted by acid menstrea; but as what is extracted scarcely amounts to $\frac{1}{3}$ of the whole, and after the separation the residuum is nearly of the same nature as before, I began to conjecture that the extracted part is accidental, and that the residuum constitutes the particular primitive earth; and this is an opinion which I have published in other works. In the mean time, however, the few vestiges of argillaceous earth which are extracted from the sapphire, and which sometimes amount to

0,02,

0,02, started a scruple of great weight; as I had often before experienced that bodies which, notwithstanding the most subtile mechanical pulverization, appear insoluble, yet upon being dissolved in another menstruum are afterwards actually taken up by the very menstrua which before were ineffectual: I therefore tried in many ways to effect my purpose. One part of alkaline salt, by means of a due degree of fire, reduces two parts of quartz or flint to a transparent strong glass; but as the proportion of salt is encreased, the glass becomes the worse, and is not only corroded by acids, but, if it contains a double quantity of salt, deliquesces in the open air: by this method a glass may be had soluble in water. The gems could not heretofore be reduced to transparent masses by means of alkali, and a quadruple quantity of salt is requisite to make them coalesce in fusion to a certain degree; but as this operation cannot safely be performed but in iron vessels, in which case the mass not only adheres obstinately to the vessel, but is at the same time loaded with iron, this method is liable to great inconveniencies; but upon trial I have found that fusion is not necessary, and that the purpose is equally answered, if the quantity of alkali be such that the particles may coalesce by an incipient fusion. Hence results a method which I have found extremely convenient in the examination of minerals,

rals, the application of which to the gems I am now to describe.

§ v. *Method by which the proximate Principles of Gems are most easily determined.*

(A) The gems are to be reduced to a most subtile powder, which may be effected by trituration and elutriation.

(B) A determined weight of this powder (the larger the quantity the better) is to be mixed with double its weight of depurated mineral alkali which has undergone spontaneous calcination.

(C) Let the mixture be put into an iron dish, the inside of which should be smooth and polished, lest the small pieces, which by calcination easily separate from the metal, be mixed with the contents of the vessel.

(D) Let the dish be placed in a wind-furnace, upon a tile, and covered by an inverted crucible, to keep off the coals and ashes.

(E) Let it be kept moderately hot for three or four hours; if the heat be too great the mass adheres to the bottom of the vessel: a blast is not to be employed, lest the iron should swell, and go off in scorix.

The firmness and coherence of the mass, and its being easily separable from the vessel, without any mixture, shew that the fire has been properly regulated; which may be easily learned by a few trials.

(F) Let

(F) Let the mass, carefully separated from the vessel, be powdered in an agate mortar; and let all that is soluble be extracted from it by marine acid, in a digesting heat.

That nothing more remains to be extracted, may in some measure be judged by the light and spongy nature of the residuum; but more certainly by the addition of a new portion of acid, which, when digested for several hours, does not take up any thing.

(G) The solution being finished, the residuum is collected and washed well, dried, and weighed. The deficiency of the former weight determines the quantity dissolved.

(H) The solution is yellow, which indicates the presence of iron: this is yet more certainly manifested by an alkaline phlogisticated lixivium, and therefore the solution should be first precipitated by this, properly saturated. The Prussian blue is collected, washed, and dried; the sixth part of which indicates the quantity of iron.

(I) The earth, freed from all the metallic parts, is precipitated by a fixed alkali, purified completely from siliceous earth: let the precipitate, washed, dried, kept red hot for half an hour, and then weighed, be plunged into six times its weight of distilled vinegar, which in the cold, in the space of an hour will dissolve all the lime, magnesia, or terra ponderosa, which is present; but
does

does not take up any considerable portion of clay, unless by a long digestion.

(K) The vinegar filtered, yields to an aerated fixed alkali all the earth which it held dissolved, which must beedulcorated and weighed. I mention particularly an aerated fixed alkali, as such an one precipitates even terra ponderosa, which eludes the caustic alkali.

(L) The nature of the precipitate thrown down from the vinegar is next to be examined: if this be put into diluted vitriolic acid, the middle salt generated will readily determine the base; for with terra ponderosa this acid generates spathum ponderosum insoluble in warm water, though a thousand times its quantity. With lime it produces gypsum, which excites scarcely any sensation of taste, and dissolves in five hundred times its weight of warm water, but is immediately thrown down from this solution by acid of sugar in the form of saccharated lime. With magnesia it forms Epsom salt, extremely bitter, soluble in its own weight of warm water, and quickly destructible by lime-water.

(M) The residuum collected (G) must also be examined, which is best done by the blow-pipe: these residua, in small portions, must undoubtedly be very minute, and therefore should not be treated in large vessels: besides, the ordinary crucibles are by no means fit, where siliceous earth is con-

cerned, nor are vessels of iron safely to be used, as fusion is necessary (§ III. c). These insoluble residua are found to consist either of particles of gems not yet sufficiently divided, or of siliceous earth, as all the other earths yield to the force of the acid.

This operation is easily performed by the blow-pipe, in the following manner:—let a piece of mineral alkali be fused in a silver spoon, and to it be added a small quantity of the residuum; the circumstances of their union are then to be carefully observed, for if the residuum enters the fused alkali with a vehement effervescence, and is all quickly dissolved, it is truly siliceous; but if it enters without effervescence, and afterwards continues rolling about in form of a powder (which, as the fused mass is transparent, may easily be seen) we may conclude that there still remain in it some particles of the gem.

(N) The residuum mentioned (L) has been alledged to be argillaceous; but to demonstrate this, let it be treated with thrice its weight of concentrated vitriolic acid, so that the liquor may evaporate to dryness; the remaining mass, if the base be argillaceous, will dissolve in twice its weight of warm water, produce a sweetish astringent taste in the mouth, yield octaedral crystals, be quickly precipitated by caustic volatile alkali, and exhibit the other characters by which alum is distinguished.

§ VI. Proxi-

§ VI. *Proximate Principles of the Gems.*

I have examined the gems in the manner above described:—the residuum of G I found purely siliceous; the precipitate of H, a genuine Prussian blue; that part dissolved by distilled vinegar in K, wholly calcareous; and what remained undissolved, argillaceous: so that I entertain no doubt concerning the quality of the principles. As to the quantity and relative proportions, many experiments are necessary to determine that point; for I have only used very small quantities, not exceeding an assay hundred. Upon subjecting the matter of the same crystal twice to experiment, a difference occurred scarce exceeding $\frac{1}{100}$; but different crystals, v. g. different rubies, differed more, even to 0,07. Doubtless in every species the proportions may vary a little, within certain limits, which yet remain to be discovered.

Here follow the mean quantities extracted from each 100, according to my experiments: as the argillaceous earth forms the largest part of all of them, I have arranged them according to the quantity of that ingredient.

		Clay.	Siliceous Earth.	Lime.	Iron.
Emerald	-	60	24	8	6
Sapphire	-	58	35	5	2
Topaz	-	46	39	8	6
Hyacinth	-	40	25	20	13
Ruby	-	40	39	9	10
			H 2		By

By clay I mean nothing more than the earth of alum, which is found in all clay mixed with siliceous powder (§ v. N). By siliceous earth I understand such as principally constitutes pure quartz, mountain crystal, and flints (§ vii). The numbers in the third column point out aerated lime: a doubt may indeed be started, whether it enters into the composition pure or aerated; if the latter be the case, the closeness of its connection with the other principles, and the smallness of its quantity, which never exceeds $\frac{1}{6}$, and is in general less than $\frac{1}{10}$, may be sufficient to prevent any diminution of weight in the fire, or any visible effervescence with acids; but the deficiency of weight which nevertheless occurs seems to indicate that it enters the composition aerated. Out of 100 parts one or two are easily dissipated in the various operations in different vessels and filters; which accounts for some of the deficiencies in the above table; but 5, 8, and much less 12 parts, could not escape proper accuracy in that analysis, which last would be the case in the decomposition of the hyacinth, on the supposition that the lime was present free from aerial acid. I could observe nothing volatile, after an exposition of several hours to a white heat, nor upon the addition of acids is any thing sublimed while they pass over into the receiver.

The

The last column shews the quantity of metallic iron, which, dissolved in acids, and precipitated by phlogisticated alkali, yields a quantity of dark Prussian blue, equal to that obtained from the several gems respectively (§ v. H). Now the iron is here present in a calcined state, and this metal, like others, has its weight increased by calcination, sometimes amounting even to 0,36: hence it follows that the quantity of martial ingredients is somewhat greater than is denoted by the numbers; and this metal gives birth to different colours, not only in proportion to its quantity but its quality, that is, the quantity and modification of the phlogiston remaining in the calx.

From the above it may also be collected, that the gems agree in this respect; that they all consist of the same principles; and that of these the argillaceous earth forms the greatest part, then the siliceous, next the calcareous, and least of all the iron;—the two first ingredients vary extremely.

The knowledge of the principles must necessarily throw some light on the properties. These gems exceed all other bodies in hardness, the diamond excepted; and we find upon analysis, that they abound in argillaceous earth. Hence we may form some judgment of the prodigious degree of exsiccation requisite to occasion such a degree of hardness. The heat of the temperate zone is found insufficient for this purpose, and

the more constant and intense heat of the tropical climate is requisite: condensation is the necessary consequence of this hardness, hence the gems are more ponderous than the other earthy crystals.

The gems, except emerald and hyacinth, resist the most intense fire; yet we know that the ruby has been softened in the focus of a burning mirror. Experience also shews, that the four principles of which they are composed, according to their various proportions, form mixtures with very different degrees of fusibility: fixed alkali attracts siliceous earth very powerfully, but scarcely acts upon argillaceous earth or lime; hence it is with difficulty it acts upon the gems in which not only the siliceous earth is in small quantity, but is also closely united with the other principles; yet in the emerald, which is inferior in hardness to the rest, the looser texture permits the alkali to attack the siliceous earth more readily; hence, when exposed to the blow-pipe with this salt, it is resolved into a powder, with a momentary effervescence. The microcosmic salt dissolves lime and argillaceous earth very well, but hardly the siliceous; yet, as this is but in small quantity, by means of the former the latter is taken up though slowly. Finally, borax, which in the dry method, strongly attracts all the principles, dissolves their combinations more easily than the other salts.

The

The same kind of delay which the argillaceous and calcareous earths occasion in the action of fixed alkali, by covering the siliceous earth, does the close union of that earth with them occasion to acid menstrua; so that, without some previous preparation with alkali, scarcely any thing can be extricated, except the lime and the metallic part.

§ VII. *Crystals allied to the Gems.*

Upon considering what has been said, I believe no one will deny that in a system of natural history the gems belong to the tribe of compound argillaceous substances; but as nature operates by insensible degrees, it will not be improper here to consider other crystals which are nearly related to the gems; for by increasing the proportion of siliceous earth a great number of substances, composed of the same materials, will appear, differing from them more or less. To this class belongs a number of stones, such as garnet, schoerl, zeolith, and quartz; the two former of these, examined in the same way as the gems (§ v.), exhibit the same principles, but in those the siliceous earth predominates over the argillaceous; yet is the connection of the principles so close, that the garnet always strikes fire with steel, and the schoerl not unfrequently. These are followed by the zeolith, the texture of which is so lax that acids separate its

constituent parts, without any other previous preparation than a mechanical pulverization. The zeolith very seldom strikes fire with steel, yet is sometimes found hard enough for that purpose: such is the white zeolith of mount Moesseberg in West Gothland, and the green in the gold mine at Adelfors: it is also very seldom transparent. The quartz forms as it were the extreme link of the chain; for this abounds so much with siliceous earth, as almost to conceal the other principles: if the analysis be attempted with a double quantity of mineral alkali, it is extremely difficult to moderate the fire so as to prevent fusion; the salt must therefore be reduced to $\frac{1}{4}$.

If the menstrua be afterwards employed in the manner described for the gems, very little clay or lime is obtained. I am not certain whether there be any mountain crystals entirely siliceous, which perhaps may be the case. I have long since declared, that I did not discover any argillaceous earth; but at the same time I observed that the experiment was imperfect.

It will be proper to conclude, by establishing the characters of the stones which have been accurately examined (for the benefit of mineralogists); and at the same time to explain their genesis and connections.

We shall first define those which belong to the class of argillacea; concerning which,

which, though the chief circumstances have been already mentioned, I think it fit to repeat them in a compendious way, and then go on to the filicea.

The Gem.

A small piece of this, exposed on charcoal to the blow-pipe, does not flow; but by a very long continued flame, the hyacinth and emerald, to which we may add the aqua-marinus and the crysolith, are softened and rendered opake.

Fused with the mineral alkali in a silver spoon, no effervescence is observed, nor any diminution, except in the emerald, the aqua-marinus, and the crysolith, which are as it were upon the confines of the schoerls; these are resolved into a powder, but a refractory one, which revolves in the globule of salt, without any sensible diminution.

It is dissolved, though slowly, by the microcosmic salt, without any commotion. Glass is not tinged, unless by the red ruby, which colours it of a beautiful green: it remains nearly transparent with the rest: with the hyacinth and emerald it grows opake upon cooling.

With borax it disappears a little sooner. An addition of lime assists the solution, which was first observed by the celebrated D. Quist, and agrees extremely well with its known composition,

The

The acids, by long digestion, extract a small portion of the lime and iron; but if the gem has been previously treated with alkali, they also take up the clay; so that the siliceous earth alone remains undissolved.

In general the gems consist of an argillaceous earth, which forms the greatest part; then siliceous earth; then lime; and, finally, iron variously modified: the proportions of each species must be determined by a great number of experiments. It also remains to be determined, whether the various colours of each species occasions any diversity; and whether the hexagonal or octaedral prismatic form constantly indicates any remarkable variety in the composition.

The ruby is generally of an octaedral form; sometimes too, accidentally, schoerlaeous: analysis has not yet determined the composition of any prismatic ruby.

The sapphire is sometimes found crystallized like quartz; sometimes it bears the form of an oblique parallelopiped; sometimes, as authors relate, it is octaedral.

The topaz commonly affects either a cubic or parallelopiped form, in such a manner, however, that the figure is seldom complete, but the number of sides is augmented by the defect in the prism itself, and particularly in the margin of the plane extremity.

The

The hyacinth also exhibits a tetragonal prism, but terminated by a pyramid (tab. i. fig. 2).

The emerald is generally an hexagonal prism, truncated at right angles.

No person devoted to the study of mineralogy should forget of how little consequence external marks are, especially as stones by triture become shapeless, or at least irregular. Science has much to expect from the analysis of crystals, both of the same and different figures, although, before the composition can be examined, they must be artificially deprived of their natural form.

The species of gems is used to be determined by the hardness; and by that quality particularly, together with the clearness, has their goodness been estimated. The spinellus is particularly worthy of observation, which is not only powdered by the sapphire, but even by the topaz; as also the crysolith, which is broken down by the mountain crystal, the hardness of which seems rather to be owing to the degree of exsiccation than the proportion of ingredients. The analysis of spinellus, of crysolith, and other varieties, will sometimes illustrate the true connection; otherwise, after the diamond, the first degree of hardness belongs to the ruby, the second to sapphire, third to the topaz, next to which comes the

the genuine hyacinth, and, fourth, the emerald.

Formerly colour was entirely confided in; but now neither can a red characterize the ruby, a blue the sapphire, a yellow the topaz, or a green the emerald.

The specific gravity varies so much, that from it nothing certain can be determined concerning the species; but the topaz is generally most weighty, from 3,460 to 4,560; the next is the ruby, from 3,180 to 4,240; then the sapphire, from 3,650 to 3,940; and, finally, the emerald, from 2,780 to 3,711; among the varieties of which last the crysolith is most ponderous.

The Garnet.

A small piece exposed to the flame flows without ebullition, sometimes into a green pellucid globule, sometimes into a black scoria.

With mineral alkali it resolves into a refractory powder so slowly, that scarce any effervescence is observed: when the iron predominates the mass grows brown.

With microcosmic salt it dissolves, without any appearance of bubbles, yielding a glass, which is green or blackish, if much iron be present.

With borax the same circumstances take place.

The acids extract scarce any thing more than

than the lime and iron ; but after preparation with alkali, they also take up the clay, which being separated the siliceous earth remains alone.

The siliceous earth forms the greatest part ; next the argillaceous ; the calcareous is in still smaller quantity.

The iron varies much ; the pellucid crystals contain about 0,02, the opaque and black sometimes so far as 0,2 : lead is seldom present. The crystals which contain tin, called zingraupen, are nearly allied to the garnets.

The form, when complete, is dodecaedral, consisting of equal rhombi ; this may be conceived as an hexagonal prism, terminated at each end by three rhombi. It sometimes puts on the hyacinthine form, though but seldom complete, especially when loaded with tin : the varieties are manifold ; the internal texture is laminated, though not conspicuously.

It yields in hardness to the topaz, but exceeds the mountain crystal.

The colour of pellucid garnet is red, sometimes more or less verging to yellow, sometimes to violet : that of the opaque is yellow, red, or blackish.

It approaches nearest to the topaz in specific gravity ; and, when copiously loaded with iron, scarcely exceeds it, being from 3,600 to 4,600.

The

The Schoerl.

A small piece exposed to the flame foams slightly, and grows soft, but can scarcely be collected into a globule, as is the case with the turmalin of Ceylon, which is akin to this, as also with the squamous schoerl, called horn-blend.

With the mineral alkali it resolves into a powder, with a slight and almost momentary effervescence.

With microcosmic salt it dissolves with a slight effervescence; and on the addition of a greater quantity, the globule begins to grow opaque.

With borax the case is the same; but the globule remains clear, unless made blackish by a large quantity of iron.

By long digestion the acids extract the calcareous earth, the metallic part, and even a great quantity of the clay; but by previous preparation with alkali, the more soluble parts separate from the siliceous earth.

The siliceous earth is in somewhat greater quantity than in the garnet; the argillaceous is next in order; last, the calcareous. The martial ingredient forms about 0,04 in the pellucid crystals; in the opaque, particularly the black, it sometimes amounts to 0,2.

Its crystalline form, when complete, is the same with that of the garnet, only the prism is more elongated; but it is very seldom

dom found perfect; hence the defect of apices and prisms of a greater number of fides. The angular longitudinal excavations are doubtless the vestiges of crystalline spiculæ formed at the same time; the hornblend is generally found concreted into squamous square lamellæ; the texture is spathaceous, though not always conspicuous.

It scarcely exceeds the mountain crystal in hardness; but the prismatic may often be cut by a knife; the squamous always.

The colour of the translucent crystals is yellow or brown, but generally green: the opaque black or green.

It is nearly equal in specific gravity to the garnet, between 3,000 and 4,000; the clear crystals are generally lighter.

The Zeolith.

A small piece exposed to the flame swells up like borax, with the greater vehemence in proportion as it is more crystalline; it finally goes off in a spumous scoria, and can very seldom be brought into a globule; a few varieties of it shew a momentary expansion of volume, and that without any ebullition.

With the microcosmic salt it swells in dissolving, but slowly, and the globule remains clear.

With borax it dissolves in the same manner.

The acids extract every thing that is soluble, without previous preparation with alkali, nay sometimes they resolve it into a jelly.

In this too the filiceous earth is more abundant than the argillaceous; the calcareous makes the smallest part; the iron scarcely exceeds 0,01.

The form of the crystals is seldom prismatic; generally an imperfect pyramid; many diverge from the same point, with broad extremities, and often coalesce into small spheres.

Its hardness is seldom so great as to strike fire with flint; generally it will not even cut glass.

The colour white and red, sometimes green, very seldom transparent.

It is not of great specific gravity, scarce exceeding 2,100.

From what has been said it plainly appears, that the garnet, the schoerl, and the zeolith, are united in the same degree of affinity as the ruby, the sapphire, the topaz, the hyacinth, and the emerald; yet in systematic arrangement the three first named are placed not only under different genera, but often under different orders. The hardness encreases in proportion to the clay: from the zeolith, through the schoerl, to the garnet, we may follow the

the natural chain, by descending through the *saxum trapp.* to the *marga*;—in this there occurs no more than a mechanical mixture. Every clay which I have had an opportunity of examining contains filiceous particles, finer or coarser, mixed with it, but always exceeding the weight of half the mass, frequently amounting to 0,7, nay to 0,8; it is generally also mixed with iron, from 0,03 to 0,20. Let us now suppose the access of a little calcareous earth, and we shall have the *marga*, which is discovered by an effervescence in acids, although the calcareous earth does not exceed 0,02. In the *saxum trapp.* analysis discovers the same principles, not separate, as in the former case, but united, and that not merely by induration, but by a species of rude crystallization; for the microscope discovers the texture to be spiculated or granulated: suppose this to be reckoned among the *saxa*, the distinguishing property of which is to exhibit particles of different natures, distinguishable by the eye; it will at least be found the most subtle of mechanical compositions, and constituting a link of the chain which unites the *saxa* with those which, although compounded, are yet so homogeneous and concreted, by the attraction of their parts, that the eye, even assisted by the glass, cannot distinguish their constituent parts; as all the integrant parts contain the same proximate principles, and in the

same proportion as the whole does. To this belong the gems, the garnet, the schoerl, the zeolith, and other derivative earths, which Mr. Cronstedt considers as primitive.

I leave it to be determined whether crystals may be formed without the help of any other menstruum than water:—to me it appears very probable that any fluid vehicle, even though not a solvent, may be sufficient for this purpose, provided the minute atoms are so suspended in it that they may freely obey the laws of their mutual attraction. The very minute molecules exert attractions proportioned to the amplitude of their surfaces; a force which is deficient in larger particles. More or less of water also seems to enter the texture of stony crystals, although, by age and exsiccation, this is generally expelled. The foaming of the zeolith in the fire is owing to moisture going off in the form of vapour, and no doubt it is a smaller quantity of this that occasions the lesser ebullition in the schoerl, still less in the garnet, while there occurs none at all in the gems.

The petrosilices also contain siliceous, argillaceous, and calcareous earth, intimately united.

On the other hand we may shew the progress of gems, through the mountain crystals to the pure flints. The clearest crystals of quartz, which come from Jetland, treated with $\frac{1}{2}$ of mineral alkali (§ v.) afterwards

afterwards yielded to acids 0,06 of clay, and 0,01 of calcareous earth; so that the same principles are found as before. If any one suspects that the whole of the insoluble residuum, by successive preparation with alkali, might in like manner be resolved into argillaceous and calcareous earth, I can inform him that I have made the attempt in vain.

§ VIII. *Of the Diamond.*

As the diamond is confessedly the chief of the gems, commonly so called, I have in the preceding pages only mentioned such circumstances concerning it as serve to evince that it differs essentially from the rest: I am far from being able to illustrate this difference further by a perfect analysis, yet it may not perhaps be altogether useless to mention so much as I have been able to discover. This operation is extremely difficult, partly on account of the extravagant price, which is required for such quantities as are necessary to make experiments which can be relied on, partly on account of the nature of the stone itself:—in order therefore to smooth the way, by removing obstacles, for those whom curiosity may invite to the examination of this gem, and whom circumstances permit to proceed more easily than I have been able to do, I shall relate such circumstances as I have discovered.

The diamond differs from the ruby and the other gems (as has been said before) by a degree of hardness unknown in any other production of nature, and particularly by its fugacity in a moderate heat (such as is sufficient to melt silver) or rather by its slow deflagration; for when made completely of a white heat it not only sensibly diminishes in bulk, but is surrounded by a little flame or cloud: but, so far as I know, the cubic or schoerl-formed diamonds have not yet been duly exposed to fire; so that it remains to be discovered experimentally whether those also entirely fly off, and if not they must lose the name of diamonds.

The diamond, urged by a very intense heat, contracts a sort of foot upon its surface.

We now proceed to examine its habits with respect to menstrua.

(A) The powder fit for these experiments is to be had by rubbing two diamonds, entirely deprived of their external covering, against one another (for it is yet doubtful whether the cortical part be entirely of the same nature with the nucleus). Such a pulverization requires larger diamonds than it was in my power to procure upon this occasion, I was therefore obliged to content myself with the examination of the powder which is for sale. It is reported of the diamond, that it yields a powder nearly black; which is certainly true of the powder

powder that is fold; but this colour is not to be considered as natural, as the blackness can be easily extracted by acids, the particles remaining white; so that the colour must be owing either to the instruments employed, or to the cortical part of the stone. Yet it may happen that black diamonds, which cannot be converted to other uses, may be pulverized; and no doubt in this case the colour will be more fixed.

(B) This powder, when well depurated by aqua regia, eludes the force of other acids; yet with the vitriolic acid it exhibits a curious phenomenon. This menstruum, poured upon the powder, and evaporated to a small quantity, grows black, and deposits black pellicles, which it is very difficult to dry; these pellicles take fire upon the approach of flame, and are almost entirely consumed, at least they leave so minute a residuum that the nature of it could not be examined. It is a question whether this is the vestige of a sooty matter: I could not observe the smoke of phlogisticated vitriolic acid proceeding from the fire.

(c) I treated the depurated powder with three times its quantity of mineral alkali, in the manner above described (§ v.): after remaining three hours in the fire the powder did not shew a sensible cohesion; however I extracted the soluble part by marine acid, and then attempted a precipitation with vegetable alkali; and in fact a light,

whitish, spongy, substance was thrown down, which dissolved in all the mineral acids, but with the vitriolic produced neither spathum ponderosum, nor gypsum, nor Epsom salt, nor perfect alum; it concreted indeed into crystals, but of an irregular form, easily soluble in water, which liquefied by the blow-pipe, and were then absorbed by the charcoal; they were of an acid yet austere taste.

(D) I again treated the undissolved powder mentioned in c with double its quantity of mineral alkali; this concreted into a firm mass, from whence it appeared that its nature was at length sensibly changed, I elixated with marine acid, and by means of vegetable alkali precipitated a portion of earth similar to that obtained in the former operation; but the insoluble residuum still floated on microcosmic salt and borax in fusion, as related in § II. A very small portion of it entered the mineral alkali with effervescence, but was no further dissolved; besides, the quantity was too small to be subjected to further experiment.

(F) These experiments, although they shew that the analysis of the diamond is difficult, shew also that it is not impossible. That there is present a portion of siliceous earth, but very closely united to the other principles, seems to be indicated by the slow action of the alkali: the precipitates shew that there is an earth soluble in acids,
the

the nature of which remains to be discovered by employing a larger quantity. The deflagration, the soot, and the black pellicles, shew the presence of an inflammable matter, unless we rather suppose them owing to heterogeneous matters adhering to the powder for sale.

(G) As the microcosmic salt seems to dissolve somewhat of the diamond by long fusion upon charcoal, I put several globules much loaded with it into distilled water, hoping that if it contained any, this, united with the phosphoric acid, would be dissolved in the water, and might then be separated by fixed alkali: nor was I entirely disappointed; the globules fell to pieces, the insoluble part of the powder fell to the bottom, the rest was dissolved by the water, and again separated by an alkali, but it fell very sparingly and slowly.

These circumstances will perhaps give some light to those who are in possession of a larger quantity of adamantine materials, by which they may be enabled to complete the analysis of this precious stone, which, on account of its clearness, its hardness, and splendor, is so much valued; although by a gentle heat it is totally convertible into vapour in the space of a few hours; while the ruby and the other gems sustain the same operation without damage.

DISSERTATION XVI.

O F

THE EARTH OF THE TURMALIN STONE.

§ I.

THE electrical virtue of this earth has been the admiration of philosophers, during the whole of the present century; and many years since I attempted to reduce its peculiar effects to constant laws: but no one, so far as I know, has yet undertaken the analysis of these stones, being prevented by their scarcity and dearness. My illustrious friend Born removed this obstacle for me, by sending me, in 1778, a parcel which was got at Tyrol, and at the same time requesting me to investigate their primary principles. Some time after, that accomplished

complished botanist, Mr. Thunberg, demonstrator in the garden at Upsal, on his return from Java and Japan, kindly brought me some turmalins, which he himself had got in Ceylon, rude, and unchanged by art. I have therefore been fortunate enough, through the kindness of these gentlemen, to be able to compare the form and composition of these the rarest production of the mineral kingdom, produced in the most distant quarters of the world. In this place I shall only consider those circumstances which illustrate the external form, the internal structure, and the component parts; deferring to another opportunity the consideration of their electric virtues, which shall be considered by themselves.

§ II. *Visible Qualities of the Turmalin Stone.*

Heretofore the turmalins were brought either from Ceylon or America, and no one so much as suspected that such were to be found in Europe; but two years since, that indefatigable examiner of the Tyrol mountains, Mt. Muller, discovered crystals of this kind, at Zillerthal, far superior, both in beauty and magnitude, to any that had been ever brought, either from Asia or America; therefore we may consider them as separated into three classes, according to the places where they are found; and we shall
begin

begin with those of the new world, which differ in certain properties from the rest.

(A) The turmalin of Brazil is frequently somewhat heavier than the others, being, with respect to distilled water, from 3,075 to 3,180: they differ in colour; and I have seen them blue, red, and of a pellucid yellow, but generally they are green.

When rough they are of a columnar form, more or less regular; but frequently are of a trigonal form, consisting of nine sides, as has been already described and delineated. The apices are often deficient, and their fracture is glassy; but sometimes, if preserved and examined, they are found low, and composed of three planes, as is explained in the Tract on the Formation of Crystals (§ 11. E, and tab. i. fig. 3.)

The prisms, exposed laterally to the light, are almost always pellucid; but when viewed in the direction of the axis a wonderful opacity prevails, and that even in the transverse section, although it be very thin: whether this holds with respect to the thinnest lamina is not yet established; perhaps this, like the following, when sufficiently diminished in thickness, will transmit the rays of light.

They yield in hardness to the quartz, and even to the other turmalins; yet they cut glass, and strike fire (though not easily) with steel.

(B) The turmalin of Ceylon varies a little in specific gravity between 3,062 and 3,295; these

these seldom come to Europe unwrought : I was therefore much pleased to get those which I mentioned. The columns of three of them were whole, about three lines in length, and two in breadth : three of the sides are broad, separated by a pair very narrow, so that at first they appear trigonal ; two of these prisms have apices, the solid angles of which are very obtuse, and formed of three irregular pentagons. All these circumstances agree perfectly with what has been said in A, of the turmalin of Brazil, and are made abundantly evident by tab. i. fig. 3. but the prisms are found furrowed longitudinally, a circumstance which plainly points out that other spiculæ had crystallized at the same time, and in contact with them. Marks of this kind frequently appear upon the surface of crystals ; and the longitudinal furrows above mentioned are very common, particularly in the schoerls and turmalins of Brazil.

The colour of the crystals is brown, and not unfrequently almost black ; but sometimes more dilute, always however more or less inclined to yellow ; which may be more easily observed by placing the column transversely between a strong light and the eye. A transverse section, half a line in thickness, still appears opaque, when exposed to the day-light, although the flame of a candle renders it semi-transparent and brown ; but
when

when made thinner, so far as $\frac{1}{8}$ of a line, it becomes pervious to the day-light.

I have also got shapeless pieces of nearly the bulk of a walnut, their subtile parts spathaceous, black, and opake; in these the electrical power is much weaker.

They nearly agree in hardness with quartz.

The electrical property of these stones seems to be unknown in Ceylon; and although, beyond doubt, the name *turmalin* is a word of the Ceylon language, yet, under the same name, Dr. Thunberg got stones of various colours, and various genera, of which, among eight varieties, not one acquired the electric quality by heat, altho' I frequently made the experiment. Dr. Thunberg also informed me, that, in the genuine language of the country, the word signifies black crystals; that they are little esteemed, and are pounded and formed into globules to serve the purpose of buttons.

(c) The turmalin of Tyrol has been so exactly described by the learned discoverer, with respect to external appearance, that nothing can be added; but, for the sake of comparison, it will be proper to repeat the principal circumstances.

The specific gravity is 3,050, that is less than any of the preceding.

The crystals are sometimes three inches in length, and exceed five lines in diameter, partly loosely dispersed among, partly firmly united to, a steatite, mixed with particles
of

of mica, not unlike the olla Jetlandica. What the matrix of the other turmalins may be, is yet unknown; but that of the Tyrol turmalin form either veins or nuclei in granite.

The figure is prismatic, consisting of nine sides, sometimes terminated by three pentagons like that of Ceylon, but in general the apices are wanting: sometimes, however, though very seldom, the pyramids are found very much acuminate, with nine sides; therefore, in general, all the known turmalins agree in form; but, so far as I know, the complete schoerl form (tab. i. fig. 1.) has not yet been seen among them by any one; — a form which, even among the schoerls themselves, is extremely rare.

Such of the Tyrol crystals as I have examined are without the longitudinal sulci; but the surface, when accurately examined, shews a slight asperity, owing perhaps to the spicular form of the surrounding matrix; but the transverse chinks, generally obscure, are found in these and the preceding, as well as in the schoerls.

The colour occasioned by reflex light is sooty, or of a brownish black, but that by refracted light of an obscure yellow; a thin transverse section appears opaque, but when the thickness is sufficiently diminished, it at length transmits green rays, as the celebrated Muller first observed, and as I have myself seen, the account is true. The Ceylon and Tyrol turmalin therefore agree in

in this, that by extreme tenuity a passage is made for the light ; but they differ with respect to the rays, which are transmitted.

(D) Many years since I observed that a variety of the schoerl, black, opake, of a complete figure, which came from Umæan Lapland, by a due degree of heat acquired electrical properties. Upon multiplying experiments I found the same thing to take place in several schoerls of Sweden, both nonagonal and spicular, of very irregular forms—these were all totally opake ; and heretofore I have not observed that property to take place in any that was pellucid.—How this electricity may be excited, and its nature explored, I defer to another place, where this matter shall be expressly considered.

§ III. *Habits of the Turmalin exposed to the Blow-pipe.*

(A) A small piece, the size of a grain of mustard, exposed upon charcoal to the apex of the flame, quickly grows red, and that without any decrepitation or other visible change : but if the action of the flame is continued for some minutes, it soon grows white, foams almost like borax, and, upon continuing the fire, is reduced to a globule ; a larger piece fuses with difficulty, but yields an inflated spongy white scoria.

This is the case with the turmalin of Tyrol and Ceylon when crystallized; but the black and shapeless pieces swell but little, and the marks of scorification which appear on the surface are brown, not white; that of Brazil cannot be formed into a globule, but exhibits a pustulous scoria.

(B) The microcosmic salt, fused upon the charcoal, attacks a small quantity of turmalin with a slight effervescence, which is yet soon at an end; and there remains a small corpuscule, almost transparent, and therefore scarce perceptible, until after the globule grows cold: this residuum is dissolved with great difficulty, but the rest of the vitreous mass surrounding it is found clear and transparent, which grows green on a farther addition while hot, and milky on cooling, chiefly occasioned by the undissolved particles. All the varieties in this respect are the same, except that the black and opaque occasion a brown colour.

(c) Borax takes up the turmalin almost in the same way, but generates heat more distinctly, and dissolves the stone more powerfully, so that it hardly contracts a perfect opacity, except the black turmalin, which added in small quantity changes the transparency to a yellow brown, but in larger quantity to a black opacity.

(D) Mineral alkali takes up the turmalin in fusion with effervescence, but a less conspicuous one than that excited by quartz: when

when a small portion of the stone is added, it is broken down into a powder, but is imperfectly dissolved: the black opaque turmalin makes the globule brown.

(E) The turmalin approaches next to the schoerl in the habit just described; the latter is, however, more completely dissolved, and with more evident ebullition, by the microcosmic salt, and also effervesces more vehemently with mineral alkali.

§ IV. *Habitudes of the Turmalin with Acids.*

(A) Three times the weight of concentrated vitriolic acid, poured on 100 lb. of subtile powder of turmalin, separated by elutriation, and exposed to distillation in a small retort until the bottom of the glass grows red hot, yields a residuum, which being boiled in distilled water, collected, dried, and weighed, is found to have lost about 16 lb. The three known varieties are, in this respect, scarce found to differ a pound or two.

The water which has extracted the soluble part, with a lixivium of burned blood yields Prussian blue; and, the iron being thus precipitated, on addition of fixed alkali a white powder is thrown down, which, with vitriolic acid, forms gypsum; which may again be decomposed by acid of sugar: the acid has therefore been only loaded with iron and lime.

The

The acid collected in the receiver is found to be purely vitriolic.

The elixated residuum, examined by the blow-pipe, swells and shews almost the same habits as the crude turmalin.

(B) The nitrous and marine acids also extract iron and lime; but in other respects have no greater effect than the vitriolic, for the residuum still remains compound; the surface therefore is not sufficiently encreased by the mechanical pulverization, so that the menstrua may be able to separate the component parts: however, the method which I followed in decomposing the gems succeeds in this case extremely well.

§ v. *Proximate Principles of Turmalin.*

(A) I treated a very subtile powder of turmalin in the same manner as the gems, with this difference, that I employed an equal quantity of mineral alkali, spontaneously calcined, and kept the mass ignited only for an hour and a half.

(B) Upon cooling, the mixture is found colligated, its surface convex, tuberculated, of the colour of wax, but internally spongy, and of a green colour, which is of a deeper hue, as it approaches the bottom, to which it adheres. The mass, when sufficiently loosened, is covered at the bottom with a black crust, which is carefully separated and weighed.

(c) The rest of the process was conducted as described on the Earth of Gems, F and N; it would therefore be superfluous to describe it again. These operations yielded the following conclusions concerning the quality and proportions of the constituent parts in an assay hundred; *viz.*

The turmalin of Tyrol.

argillaceous earth	-	-	42
filiceous earth	-	-	40
calcareous earth	-	-	12
iron	-	-	6

Turmalin of Ceylon.

argillaceous earth	-	-	39
filiceous earth	-	-	37
calcareous earth	-	-	15
iron	-	-	9

Turmalin of Brazil.

argillaceous earth	-	-	50
filiceous earth	-	-	34
calcareous earth	-	-	11
iron	-	-	5

(D) By argillaceous and filiceous earths, I here understand those earths freed from all heterogeneous matter; but the calcareous earth appears to be nearly saturated with aerial acid, as otherwise a greater defect is observed than can be supposed in an accurate operation. That no effervescence takes place with acids is easily accounted for, when we consider

consider that only a very minute portion of calcareous earth adheres so very closely to the other constituent parts, that it has sufficient hardness to strike fire with steel: the iron is dephlogisticated, and the crude turmalin does not shew the least sign of detonation with nitre.

As to the proportions of the constituent principles, I have set down such as experiments suggested; but it is necessary to take the medium of a number of experiments, as nature does not observe so exact a proportion in the admixture of the principles of bodies, but that sometimes there may be some hundredths too much or too little; besides, a series of operations (notwithstanding the greatest possible accuracy) will sometimes add a little weight, or sometimes diminish, which is particularly sensible when very small quantities are used. Thus, in the present instance, I have not yet been able to subject to experiment more than a few assay pounds: in these experiments I constantly found the same ingredients, but the proportion of them required some correction. The difference of habits discovered by the blow-pipe manifested some difference between the Tyrol and Ceylon turmalin; but whether the above proportions be exact, remains further to be examined.

(F) That water enters the composition may be gathered from their undergoing the

same ebullition in fusion as the zeolith does, which certainly contains water; but the quantity of matter to be examined only permitted me to make one trial with this view. I kept 100 lb. of Tyrol turmalin grossly powdered for half an hour in an obscure red heat; but upon cooling found no difference in weight, nor did I expect any, as a white heat is necessary to fusion: I therefore increased the fire to a sufficient degree, but the fragments of turmalin were agglutinated to the crucible, nay, had entered into a sort of union with it; I therefore made the experiment in another, which was tedious and troublesome:—I took 25 assay pounds of fragments of turmalin, each of which I separately reduced to white scoriæ by the blow-pipe, but I did not find that the weight was sensibly diminished; a proof that there is either no water at all, or only a very small quantity.

§ VI. *The Place belonging to the Turmalin in a System of Mineralogy.*

Being acquainted with the nature and proportion of the earthy principles which enter into the composition of the turmalin, we cannot hesitate to place it among the argillaceous species, since the chief part of it is constituted by this earth, which, even when it is present in smaller proportion, communicates

communicates its peculiar properties to the whole mass.

In the gems we find the same principles, and clay in greater proportion than any other earth: the turmalin can scarce be referred to this class, because its structure is so much looser.

The phænomena it exhibits, when treated with the blow-pipe, approach nearly to those of zeolith; but of this filiceous earth constitutes the principal part: and the constituent principles cohere so weakly that acids are capable of extracting them without any previous treatment with fixed alkali, and the heat of distillation of expelling most of the water. It is more closely allied to schoerl; for the turmalin not only resembles this in the form of its crystals, and the phænomena it presents, both with heat and solvents, but also sometimes in being electrical, a property which shall be particularly examined in the sequel; it however differs in containing more filiceous earth, and some other circumstances before noticed (§ III. E).

DISSERTATION XVII.

OF

THE FULMINATING

CALX OF GOLD.

§ 1. *Historical Introduction.*

ALTHOUGH the wonderful fulminating property of gold was known at least in the 15th century, it has not yet been examined by philosophers so as to determine with certainty the cause of the prodigious noise and stupendous explosive force; yet in this explosion there occur phænomena highly worthy of attention—phænomena which not only indicate very singular properties, but are of such

such a kind that the causes of them, well understood, must certainly throw great light upon the theory of chemistry. The following experiments, which are partly new, and partly such as have been described by others, but carefully revised and corrected, will I hope tend to illustrate the subject. But before we enter upon them it will be proper briefly to relate the attempts of others, who have made this business their particular study.

Whether or not the ancient alchemists were acquainted with the fulminating property of gold, we are ignorant; their arcana being involved in an enigmatic and obscure stile. Basil Valentine is perhaps the first who has clearly described the method of communicating this property to gold: he directs the metal to be dissolved in aqua regia made with sal ammoniac, and then precipitated by vegetable alkali, to be twelve times washed with water, and finally dried in the open air, where the sun's rays cannot reach the powder; he forbids it to be dried over a fire, as it explodes with a gentle heat, and flies off with inconceivable violence; but he has not distinguished this calx by any peculiar name.

Many chemists afterwards performed this operation, but here and there we observe some small difference.—O. Crollius calls it *aurum volatile*, and is scarce willing to have it dried, even though carefully, and in bal-

neo maris ; but above all forbids the stirring it with an iron spatula. J. Beguin added the epithet *fulminating*, which has been since generally adopted ; although we sometimes meet with the terms *sclopetans* and *ceraunochryson*.

The necessity of employing volatile alkali in this operation was but little regarded until the present century ; for Hellot tells us, from Grosse, that gold dissolved in a mixture of nitrous and marine acid, fulminates better when the volatile is used than when the vegetable fixed alkali is employed ; but that if the menstruum be made with sal ammoniac, the latter precipitate is best. Zwelf calls the gold precipitated by fixed alkali, without the fulminating property, aurum mutum. Ettmuller and Hoffman found that precipitated by volatile alkali always fulminating.

Becher found the fulminating powder, when well washed, heavier than the gold employed by $\frac{1}{3}$; Lemery by $\frac{1}{4}$; and Jungken by $\frac{1}{3}$: it is doubtful whether Barner ever made the experiment, as he affirms that in order to produce the best effect it should not be washed with water (compare § x). Many also, after him, have thought that by boiling in water the fulminating property is destroyed, or at least diminished ; the celebrated Beaumé was the first who detected that error.

That

That water loaded with fixed alkali when boiling takes away all the explosive power, is asserted, if I mistake not, by all the moderns, following the author of Homer's Golden Chain. Kunckel found this property destroyed by vitriolic acid. Rolfincius, and others, contend that marine acid has the same effect; and Mr. Spielman extends that faculty to all the acids, even to vinegar: yet Cassius relates that aurum fulminans exploded most violently when marine acid dulcified was distilling from it. Basil Valentine attempted, not without success, to subdue the fulminating property by means of sulphur.

A single scruple of aurum fulminans explodes, as Crollius asserts, with more force than half a pound of gun-powder, and propagates its action downwards; yet H. F. Teykmeyer frequently shewed in his lectures that it would throw a florin upwards above six ells; and the same effect had been observed by many others before him.

A great number of experiments were made before the Royal Society at London, in order to determine the comparative forces of these two powders:—equal parts of gun-powder and of aurum fulminans were included in iron globes, which were placed among burning coals; those which contained the former were burst with violence, while the other remained perfectly silent. But if the globe containing the gun-powder
did

did not exceed the bigness of a pea, the globe remained unhurt, although the contents had been inflamed.

Many unfortunate accidents however shew that the greatest caution is necessary in handling aurum fulminans: Orschal relates, that this powder, ground in a jasper mortar, had by its explosion burst the mortar into a thousand pieces: the celebrated Dr. Lewis gives an instance of the same in England; nay, Dr. Birch tells us that by an explosion of this kind doors and windows had been violently torn to pieces: but Mr. Macquer gives a very melancholy detail of a misfortune which happened in his own presence:—a person of 22 had put some aurum fulminans into a phial, but unfortunately did not observe that a few particles adhered to the neck; upon shutting it therefore, as is usual, by twisting the glass stopper, the few particles exploded with such force as to throw the young man among the furnaces of the laboratory, with the loss of both his eyes, occasioned by the splinters of the glass.

The sentiments of chemists concerning the cause of the fulmination differ very much; the opinions of those who speak in words so obscure that it is scarce possible to reduce them to sense, we shall omit; the rest may be divided into four classes, some ascribing it to an aerial, some to a saline, some to a sulphureous principle, and finally, there

there are others who suppose it to depend upon several of these united.

F. Hoffman attributes it to humidity and an elastic vapour dilated by heat; but the celebrated Dr. Black affirms it to be owing to fixed air copiously and suddenly set at liberty. A. Peterman asserts this power to depend upon the union of the solar principles with nitre; but others, and indeed the most of the moderns, substitute a species of nitre totally volatile, which is commonly called *nitrum flammans*. Cassius speaks of sulphureous particles of gold which are discharged from the bond of salts, as being substances of an opposite nature, by means of the fire; and, upon getting loose, give as violent a concussion to the air, as sulphur and nitre in common gun-powder; but very lately M. Beaumé proposes as the cause, a nitrous sulphur deflagrating violently; and supports this opinion with many specious arguments. Notwithstanding all these explanations, many philosophers are still of opinion, that the phænomenon is not yet accounted for: such are Boerhaave, Macquer, Spielman, and others.

If in our days a certain *frigor vibergenſis* were necessary, a very violent one might be best obtained by means of this calx of gold; for no substance hitherto known explodes with a louder noise. Dr. Lewis compares the report occasioned by gun-powder to the sound of a long and lax cord; and that
of

of aurum fulminans, to that of a short and tense one. But in mines it cannot be substituted for gun-powder, as, when it is close shut up, it is reduced without noise or violence, as we have seen before; besides, this powder must be fired by heat, and not by sparks.

The celebrated Stahl says, that aurum fulminans, treated with sulphur, as hereafter described, is used as a pigment by goldsmiths and enamellers. Dossie mentions this as a valuable secret.

Formerly, three or four grains of this powder were given as a diaphoretic of extraordinary power, as we are told by Crollius and Beguin. Rolfincius relates an example of its cathartic virtue: his words are these, *Illustris regiae Suecicae militiae generalis Pannerius* (doubtless *Banner*) *gravissimo colico dolore infestatus, clysteribus aliquot officium non facientibus, habuit melius, commota alvo, assumptis auri fulminantis granis 6 in cochleari pleno vini Malvatici.*

§ II. Preparation of Aurum Fulminans.

This powder may be prepared in two different ways; for either the gold is dissolved in a menstruum composed of nitrous acid and sal ammoniac, and the solution precipitated by a fixed alkali, or the solution is performed by aqua regis made without sal ammoniac (which may be done in various

rious ways) and the precipitation effected by volatile alkali. Aqua regis without sal ammoniac may be prepared by mere mixture of nitrous and marine acid, or by nitre dissolved in marine acid; or, finally, by sea-salt dissolved in nitrous acid. It is obvious, that instead of nitre or sea-salt, other salts containing these acids may be employed. *Menstruum sine strepitu* was a name formerly given to a liquor consisting of a little water with nitre, sea-salt, and alum, in which gold-leaf was dissolved by triture; in this case the acid of the alum expels the other acids, which therefore, by their union, form common aqua regia.

By whatever method the gold be dissolved and precipitated (provided the volatile alkali is present, either in the menstruum or the precipitant) a yellow precipitate is obtained, which, when well washed in water, and cautiously dried, is commonly called aurum fulminans. The weight of the calx, well washed and dried, exceeds that of the gold employed, by about $\frac{1}{3}$.

The dissolved gold is more readily precipitated by volatile than by fixed alkali.

§ III. *Properties of the fulminating Calx of Gold.*

The phænomenon which has chiefly rendered this powder famous, and has given occasion to the name, is the prodigious noise occasioned

occasioned by the explosion of a few grains exposed to heat in a metal spoon, either over a candle, coals, or a red hot iron ; or by any other means sufficiently heated. How this phenomenon takes place, we shall see hereafter.

(A) A degree of heat between 120° and 300° , the degrees at which the nitrous and vitriolic acids boil, is sufficient for this purpose ; but whether the solar rays, without concentration, can produce the same effect, as some persons assert, I have not yet been able to determine ; but am inclined to doubt of their possessing such efficacy, unless the aurum fulminans be extremely well prepared ; but if the mass be inspected just as it is about to explode, in the very instant preceding the explosion no other change is observed than its colour verging to black, upon which it instantly is dispersed with an obscure flash, and a wonderfully acute sound : the same effect is observed whether the powder be surrounded by common air, or aerial acid.

(B) By simple triture, or percussion alone, this powder is inflamed, and explodes with great violence, whence melancholy accidents have sometimes happened ; but every sort of aurum fulminans is not susceptible of explosion by these means. By boiling in pure water, or (which is better) in an alkaline lixivium, or (which is best of all) by a due degree of calcination, it is rendered so

prone to inflammation, that by the electric spark, nay often by the smallest agitation with a piece of paper, it explodes; the common aurum fulminans is also exploded by the electrical shock.

(c) A portion weighing from 10 to 12 grains of aurum fulminans, exploded on a metal plate, perforates and lacerates it; a smaller quantity forms a cavity in the plate; and a still smaller only scratches the surface; an effect which is never produced by gun-powder, though in much larger quantity.

(d) A weight laid upon the powder is thrown upwards in the moment of explosion; and if it be of silver, it is found gilded with a yellowish spot. In the same way is marked the support, if it be made of silver or copper.

Besides, a large grain, advanced near to the side of the flame of a candle, blows it out with violent noise; and a few ounces exploding together, by incautious drying, has been known to shatter the doors and windows of the apartment: hence it is evident, that aurum fulminans exerts its force in all directions; yet it cannot be denied, that it strikes bodies with which it is in contact more violently than those which are at a small distance, though in its vicinity: thus, if a small portion of it explodes in a paper box, it lacerates only the bottom, unless the top be pressed down close, in
which

which case it perforates both the top and bottom.

(E) When carefully and gradually exploded in a glass phial or a paper box, it leaves a purple foot, in which are found many particles of shining gold; nay, if the quantity exploded be large, several grains remain totally unchanged; for it is only the stratum next to the heat which is inflamed, as may be shewn by an easy experiment, namely, if the fulmination be performed over a large surface of burning coals; for in that case a number of decrepitations will be heard, occasioned by grains of the aurum fulminans dispersed in a perfect state by the explosion of the inferior strata.

(F) When moist, it does not explode all at once, but each grain, in order as it becomes dry, decrepitates in a manner similar to common salt.

(G) In glass vessels closed, or with their mouths immersed in water to prevent breaking, a moderate quantity explodes indeed, but with a very weak noise, so as scarcely to be perceived; but in the moment of explosion, an elastic fluid breaks forth, which, when cool, occupies about seven inches, if half a drachm of the powder has been used; this air extinguishes flame, destroys animal life, rejects pure water, and does not even precipitate that which contains lime in solution.

(H) In

(H) In metallic vessels of sufficient strength and perfectly closed, aurum fulminans, exposed to heat, is reduced silently, and without any marks of violence: if the access of air be only partially prevented, the metallic vessels are more violently acted upon; but if they are of sufficient strength, and very small chinks afford vent to the air, the smoke indeed penetrates through, but gently, and without bursting, as I twice experienced in about half a scruple of this calx, with which I filled a brass rose, and stopped the aperture with a strong screw; for in this case the vapour made its way through the pores with a hissing noise.

§ IV. *Means by which the fulminating Property may be destroyed.*

This may be effected by various methods, and that even without additament.

(A) For instance, by fire alone, slowly and cautiously increased: let a degree of heat at first be employed near to that which usually occasions the explosion; this must immediately be slackened a little, and thus alternately be increased and diminished: upon continuing this operation a long time, the aurum fulminans gradually becomes capable of resisting a fire more and more intense, at length grows of an obscure black, and loses all its fulminating properties: this experiment requires considerable pa-
 VOL. II. L tience;

tience; for, unless the fire be skilfully regulated, and the smallest agitation and friction avoided, the powder explodes at once with its usual vehemence, and flies off in the form of vapour.

(B) This effect is more commodiously obtained by the addition of a dry substance of any sort, provided it be well pulverized, and intimately mixed with the aurum fulminans by trituration, so that the particles of the latter may be separated as much as possible; for this being done (which may be easily tried with small portions) the mixture may safely be exposed to the fire.

Sulphur has been long used for this purpose in the following way:—let powder of sulphur be mixed with an equal weight, or half its weight, of aurum fulminans, then melted for a short time with a gentle heat without smoke, after this with evaporation, and, finally, burned with deflagration: this is done much more easily by putting the mixture by degrees into a crucible previously so heated, that the sulphur will flame upon touching it; for in this case, although a few grains decrepitate, they are not dispersed. This may be effected with still greater ease, by adding the aurum fulminans gradually to the sulphur in fusion.

The salts, either alkaline or middle, are sufficient for this purpose, and are used with great advantage, because they may be afterwards separated by ablution.

This operation succeeds also with the earths, nay, with concentrated vitriolic acid, and other liquors, as we shall afterwards see (§ VIII. and IX). In a word, aurum fulminans is deprived of its fulminating property, if exposed to a degree of heat sufficient to cause the explosion, if at the same time the fulmination be prevented by any means whatever, even by external force.

§ v. *Chief Opinions concerning the Cause of the Explosion.*

Various explanations of this explosive property are to be found among chemists; some of which, being delivered in an unintelligible manner, we may properly pass over, and consider the others as distributed into four classes; for philosophers have thought, that this wonderful phenomenon might be attributed to a saline, a sulphureous, or an aerial principle, or, finally, to many of these jointly; yet some there are, who with justice consider all the explanations hitherto given as insufficient.

§ VI. *Different Opinions concerning the Cause, supposed to be saline.*

Those who attribute the fulmination to a saline principle, do not yet agree with regard to the species of salt.

(A) Some consider the falsified fixed alkali (which is called *sal digestivus*) adhering to the calx, and decrepitating in the heat, as the cause of this phenomenon; but these gentlemen do not consider, that this salt is neither present nor regenerated, when the gold dissolved in nitrous acid, containing *sal ammoniac*, or in a mixture of nitrous and marine acids, is precipitated by volatile alkali; and, besides, if the latter of these solutions be precipitated by fixed alkali, the precipitate is not fulminating, though the digestive salt in this case is present.

(B) Others have recourse to common nitre, which is known to detonate with phlogiston: but here the same difficulties occur, for neither is nitre always present in the preparation of *aurum fulminans*, nor, when it is present, is the calx always found fulminating; besides, this salt does not detonate with the calx of gold, but on the contrary (by the method described § IV.) serves to reduce it.

(C) The nitre, called *nitrum flammans*, seems to be very different in its nature; this salt consists of nitrous acid saturated with volatile alkali; and, from what has been already said, the presence of this substance in *aurum fulminans* is obvious; besides, it possesses the property of detonating, without the addition of phlogiston; and, besides, we are told by authors, that the vitriolic acid and fixed alkali destroy the fulminating property; the
 2 former

former because it is more powerful than the nitrous acid, and the latter because it expels the volatile alkali. This opinion therefore carries with it an appearance of probability, and almost all the moderns have embraced it. In order however to acquire a certain knowledge of this matter, if possible, I instituted a number of experiments, the chief of which I shall now relate.

§ VII. *Fixed Alkali does not destroy the fulminating Property by the Via humida.*

The fixed alkali does indeed deprive gold of its fulminating power, by fire, as described in § IV. but in that case it acts in no other way than any other matter interposed between the particles: but whether it acted in virtue of its alkaline quality, was tried in another way.

(A) Six parts of alkali of tartar were therefore well triturated in a glass, with one of the calx, and a few drops of water. This being done, a little more water was poured on, and all the liquor evaporated in a digesting heat. During this operation no vestige of urinous smell could be perceived: the mixture, when dried, and freed from the saline parts by ablution, not only fulminated, but with a noise far greater than usual.

(B) The same experiment was made in another way; namely, one part of aurum

fulminans was boiled for half an hour in 200 of caustic lixivium; but its power was rather increased than diminished by this: water was added, to prevent the lixivium from acquiring too great a degree of heat, which would of itself destroy the fulminating property (§ IV.)

One circumstance I shall remark, *viz.* that no difference of efficacy was observed, whether the calx was precipitated from its menstruum quickly or slowly.

§ VIII. *Whether Acids destroy the fulminating Property.*

As vitriolic acid requires near thrice a greater degree of heat to make it boil than pure water, it is no way surprizing that boiling in this acid should destroy the fulminating quality, as before observed: but, in order to determine whether that was the true and only cause, the acid was so far diluted with distilled water, that it could not sustain too high a degree of heat, and the aurum fulminans boiled in it for half an hour, when, after being welledulcorated, it exploded as usual: nor does it, when triturated and digested with the strongest vitriolic acid, lose any of its power, but by boiling many particles acquired the metallic splendor of gold.

(B) The marine and nitrous acids, when boiling violently, possess a greater degree of heat

heat than boiling water, but inferior to that which is necessary for fulmination; hence it happens, that the latter of these fluids not only fails of destroying the fulminating power, but the precipitate, while wet with this, decrepitates in the same way as if penetrated by water.

(c) But the marine acid dissolves this calx more easily, and upon evaporation almost always reduces a part; for this menstruum naturally contains phlogiston, which, by means of superior attraction, it is obliged to yield to other bodies: but the solution itself, precipitated by fixed alkali, yields a calciform and fulminating gold. Whatever is not dissolved by digestion, when welledulcorated seems to have lost scarcely any thing.

(d) Upon adding vinegar, and distilling to dryness, the fulminating power is found to be destroyed: this however is only to be understood of the residuum, either notedulcorated, or reduced by means of heat.

§ IX. *The fulminating Property may be communicated to Gold, without the Intervention of nitrous Acid.*

In order to discover whether the nitrous acid be altogether necessary; and also how the process would succeed without the marine acid, the following experiments were undertaken.

(A) A calx of gold (not fulminating) boiled in vitriolic acid a little diluted, yielded a yellow solution, for the precipitation of which a large quantity of caustic volatile alkali was necessary: the precipitate was small, but, after beingedulcorated, fulminated by heat.

(B) Another portion, boiled in nitrous acid perfectly freed from marine acid by means of silver, yielded, though not without boiling violently, a red solution, of the same colour as that of platina in aqua regia: this, upon the simple addition of water, let fall a calx, which, digested with caustic volatile alkaliedulcorated and dried, exploded in the heat in the same way as gold precipitated from the nitrous acid by caustic volatile alkali, when washed and dried.

(C) Of all acids the muriatic best dissolves the inert calx of gold; even without heat it dissolves it readily: a solution of this kind was precipitated by volatile alkali, as before, and the sediment, when washed and dried, fulminated as usual.

§ x. *The Fulmination is not effected by a Nitrum Flammans.*

In order the better to understand the detonating property of the nitrum flammans, let a portion of it be put into a cold glass, then let the heat be raised as quick as possible,

fible, yet no detonation enfues, but the salt is resolved into vapour, and flies off: let the glafs be hot at firft, and the salt will liquefy, but not detonate; but if it fall upon an ignited glafs, it kindles and deflagrates, with a noife and a yellow flame: it is in vain therefore to affign this falt as the caufe of the fulmination.—Besides,

(A) The found of this detonation is not at all correspondent to that occafioned by fulmination; but let us fuppofe it to be encreafed by the weight of the superincumbent particles of gold, which prevent it from breaking forth, until the tendency to explosion, increafing more and more, becomes at length able to remove the obftacle: but fimple detonation, unimpeded, requires a heat equal to ignition; when impeded it fhould therefore require a greater degree; now aurum fulminans requires a much fmaller heat, therefore fome other caufe befides detonation muft operate here.

(B) The precipitate of gold, which does not fulminate, I have endeavoured to unite by dry triture with nitrum flammans; but by this method could obtain nothing more than a powder which crackled in the heat.

(c) As the falt is fo eafily folvable in water as readily to attract humidity from the atmofphere, I thought that (if prefent in aurum fulminans) it might be feparated by boiling: one part of it was therefore boiled with 600 of diftilled water for a whole hour,

hour, and after the interval of a day the same was boiled with 600 parts of fresh water for the same length of time, but in vain, for the powder fulminated with as great violence as before.—We may here observe the gradual efficacy of water: thus, if gold precipitated from the menstruum be notedulcorated, it scarcely fulminates at all; if washed a little with cold water it explodes indeed, but with a very obtuse sound, and a diffused flash; but if it be washed with a large quantity of water, or with hot water, it occasions an acute sound and an obscure flash. The efficacy of the water, when brought to this degree, is neither encreased nor diminished by boiling, as far as the ear can judge, which we are obliged to trust to, so long as we are destitute of a more accurate measure.

No one can wonder at the destruction of the fulminating quality in Papin's digester, upon considering the degree of heat which it there sustains (§ IV).

(D) Gold dissolved in dephlogisticated marine acid, and precipitated by volatile alkali, possesses the fulminating property, though nitrous acid has never touched it. If any one imagines that gold dissolved in aqua regia can never (by the humid way) be perfectly freed from nitrous acid, he must at least confess that that acid is altogether absent when dephlogisticated marine acid is employed to dissolve the gold: this acid
contains

contains a certain quantity of phlogiston, which it is obliged to yield to manganese, and then becomes a yellow vapour, which dissolves all metals, by taking from them that quantity of phlogiston which would otherwise impede the solution; and the acid itself is thus restored to its natural state, and the combinations thus formed yield metallic salts containing a perfect marine acid.

From all this we conclude, that, even though the nitrum flammans were, which it is not, sufficient to explain the phenomena, yet it could not be admitted as the true and efficient cause.

§ XI. *Volatile Alkali necessary to the Fulmination.*

(A) In order to discover what the volatile alkali contributed to this effect, a non-fulminating precipitate was digested for some hours in caustic volatile alkali, afterwardsedulcorated and dried: this fulminated perfectly.

(B) Left some suspicion should remain, of a remnant of the aqua regia adhering to the precipitate, notwithstanding theedulcoration, the experiment was repeated in this way: after digestion for 24 hours in vitriolic acid, the precipitate was washed in pure water, then immersed in aqueous and spirituous solutions of alkali, both mild and caustic; but the event was the same.

(c) An

(c) An inert calx of gold, by simple digestion in a solution of any salt containing volatile alkali, whether the saturating acid be vitriolic, nitrous, or marine, possesses the fulminating property. The golden calx is found increased in weight about 0,2, and the residua of the ammoniacal solution contain a superabundant acid: therefore the non-fulminating calx of gold is capable of abstracting a certain quantity of volatile alkali from the ammoniacal salts; which portion may again be separated by distilling the aurum fulminans well washed with vitriolic acid; for in the neck of the retort a vitriolated volatile alkali is found sublimed.

(d) Finally, we should recollect that gold cannot receive the fulminating property without volatile alkali (§ 11).

§ XII. *Whether the Fulmination be effected by a Sulphur.*

Most of the ancient chemists, and not a few of the moderns, speak of a certain solar sulphur, nay, some contend that gold is wholly a sulphur; hence they derive the effects produced in the present case, endeavouring to persuade themselves and others that here the same principles co-exist as in gun-powder and pulvis fulminans, namely, sulphur, nitre, and tartar. But opinions like these, at once subtle and obscure, we shall leave involved in their own darkness,

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The following observations will shew that it is without reason any sulphur is suspected.

(A) Of late the fulmination has been attributed to a nitrous sulphur, generated in the precipitation, and adhering to the calx. The wonderful fulminating property of this calx is supposed to be sufficiently accounted for by the detonation of nitre; but the presence of it in aurum fulminans has hitherto been sought after in vain. As vitriolic sulphur may be dissolved in a caustic lixivium, and precipitated by acids, it seems probable from analogy that the same property should belong to nitrous sulphur; but upon boiling in a caustic lixivium (§ VII.) the fulminating power is found entire, and, upon the addition of acids to the lixivium, no particular smell is observed, and the gold is precipitated, but in exceeding small quantity.

(B) I have also employed vitriolic ether, that most powerful menstruum of all inflammable bodies; this, on digestion for some days, begins to be tinged yellow, a golden pellicle appears upon the surface of the liquor, nay, a few grains of the calx lying at the bottom exhibit the splendor of gold: upon evaporation to dryness this solution yields splendid gold, not at all fulminating.

Gold separated by ether from aqua regia, destitute of volatile alkali, when precipitated
by

by volatile alkali fulminates; but is totally void of that property, when thrown down by fixed alkali.

(c) Common sulphur is not soluble in spirit of wine, unless when both these substances meet in the form of vapour; but we could not thence venture to conclude the same of nitrous sulphur: I therefore digested aurum fulminans for eight days in rectified spirit of wine, but neither was the liquor tinged, nor did any thing remain on evaporation, nor was the calx found to be changed.

It is worthy of observation, that the non-fulminating calx of gold, upon digestion for a few days in rectified spirit of wine, grows black, and acquires a fulminating property, but weak, and scarcely simultaneous.

§ XIII. *Whether the Fulmination be occasioned by Aerial Acid.*

That substance which enters into the composition of certain bodies, which, though very much resembling air, is substantially different from it, has been called by modern writers fixed air, although it really is a true and distinct acid: some contend that this forms the bond of union between the particles of bodies, and in that state is fixed, and deprived of its elasticity; and that when a considerable quantity of this recovers its elasticity at once, it must strike violently upon

upon the atmospheric air, thereby exciting undulations, and consequently a sound, which is various according to circumstances.

They think, that in the present case the gold in solution loses its fixed air, which it again recovers in still greater quantity during the precipitation, as the calx is found encreased in weight;—the precipitate being then exposed to fire, this aerial matter is suddenly forced to quit the calx, notwithstanding the weight of the particles of gold; by means of which, however, the eruption being impeded, is made far more violent; hence the extraordinary noise.—The following observations will shew clearly that in this instance the fixed air does not act in this case.

(A) The elastic fluid which may be collected during the fulmination, is not absorbed by water, nor does it precipitate lime from that fluid (§ III. c).

(B) Gold precipitated by mild fixed alkali, does not fulminate, unless the menstruum contains volatile alkali.

(C) Gold precipitated by caustic as well as mild volatile alkali, fulminates.

(D) Gold in its precipitation rejects the aerial acid.

§ XIV. *The Phænomenon of Fulmination explained.*

From what has been said it is plain that the vitriolic and marine acids are no less favourable

vourable to fulmination than the nitrous (§ IX.) yet that neither of these is otherwise necessary than as dissolving and attenuating the metal (§ XI.); and finally, that no fulmination takes place without volatile alkali (§ XI.): the question therefore is, how the volatile alkali acts in this case? To this question I shall endeavour to give the best answer which experience has pointed out.

(A) From the very nature of the thing it is plain that so great a report, and so violent an explosion, could not happen but by means of the copious and instantaneous eruption of some elastic fluid violently striking the common air; and that this is the case in the fulmination we have already observed (§ III. G); but, for the better understanding this operation, it is necessary to consider the constituent parts of aurum fulminans, namely, the volatile alkali and the calx of gold.

(B) It cannot be doubted that volatile alkali always contains phlogiston: to pass over other proofs, it may be sufficient to mention its detonation with nitre. Now this phlogiston may be separated by means of a superior attraction; so that the volatile alkali is decomposed, and the residuum dissipated in the form of an elastic fluid altogether similar to that which is extricated during the fulmination: the source then from whence the elastic fluid is derived is obvious; it remains

mains to examine the medium by which the volatile alkali is dephlogisticated.

(c) In those metals which are called perfect, so great is the firmness of texture, and so close the connection of the earthy principle with the phlogiston, that by means of fire alone these principles cannot be disunited; but when dissolved by acid menstrua, they must necessarily lose a portion of their phlogiston, and therefore, when afterwards precipitated by alkalis, which cannot supply the loss, they fall down in a calcined state: they however attract phlogiston so forcibly that they can be again reduced to a metallic state without additament, merely by an intense heat penetrating the vessels. Gold therefore is calcined by solution; and this may be laid down as a fundamental position, being expressly treated of, and, if I mistake not, undeniably demonstrated, in another place.

(d) Let the powder, now consisting of calx of gold and volatile alkali intimately united, be exposed to an heat gradually increasing, and let us examine what will be the consequence:—the calx, which is united with the volatile alkali, by the assistance of a gentle heat seizes its phlogiston, and when this is taken away the residuum of the salt is instantaneously expanded into the form of an elastic fluid, which is performed with so much violence, that the air must yield a very acute sound. The calx may indeed be re-

duced by means of a very intense heat alone; in which process the heat is decomposed, and yields its phlogiston to the calx, upon which the other principle, the pure air, is set at liberty. But in the present instance a smaller degree of heat seems to be necessary than when the volatile alkali is absent; hence we may impute the reduction chiefly to it, although it can scarcely be denied that some particles are reduced by the heat alone. This we collect from the obscure flash; for light, so far as experiment has yet shewn, is nothing more than the matter of heat, with a superabundance of phlogiston: a part therefore of the calx being reduced by the phlogiston of the heat, the pure air (the other ingredient) is set at liberty, and attacks the superfluous volatile alkali (which is now hot) and is so loaded with the phlogiston of the alkali that it exhibits the appearance of light: for this cannot be attributed to the surrounding air, as the phenomenon takes place even in aerial acid. But that the volatile alkali can in this way produce a flash, is evidently shewn by another experiment: for if this salt be thrown into an hot crucible, it instantly exhibits a flash.—The volatile alkali, in its ordinary temperature, does not yield its phlogiston to pure air; but that principle, being of itself very fugitive, upon the access of heat is much more easily set at liberty, and unites with the pure air.

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A single cubic inch of gun-powder generates about 244 of elastic fluid, but the same quantity of aurum fulminans yields at least four times as much; and hence we may easily understand the difference in their explosive force.

The above explanation of the report, founded upon the knowledge of the composition of heat, and of aurum fulminans, seems abundantly satisfactory, but some phenomena still remain not sufficiently accounted for.

That careful calcination should destroy the fulminating property, is not to be wondered at (§ IV. A), as the volatile alkali is the indispensable material cause (§ XI.); but the peculiar alacrity which it acquires before the explosive force is totally extinguished, depends upon the nature of the materials, and of the operation. Thus the heat, when inferior to that necessary for fulmination, acts upon both the principles of the aurum fulminans, it prepares the metallic calx for a more violent attraction for phlogiston; it also acts upon the phlogiston of the volatile alkali, and loosens its connection: these two circumstances must tend to the union producing the explosion. But this effect has a maximum, and at this period the slightest friction supplies the defect of necessary heat, and produces the fulmination. The calcined gold also seems to collect and fix the matter of heat, though

still insufficient, by means of its phlogiston, in a certain degree; so that, by means of friction, though but very slight, it becomes capable of exerting its force: but when the heating is often repeated without producing its effect, the volatile alkali is by degrees dissipated, and at length so much diminished that the calx becomes inert. That this dissipation is promoted by enlarging the surface is evident, and this explains the mode of action of the heterogeneous particles interposed between those of the calx (§ IV. B).

But if aurum fulminans is capable of producing such a prodigious quantity of elastic fluid, how does it happen that it remains mute and inert when reduced in close vessels? This I take to be the reason—every elastic fluid in the act of breaking forth requires a space to expand in; if this be wanting it remains fixed, as has been already demonstrated: taking this for granted, a calx of gold cannot be reduced in close vessels either by heat or by the phlogiston of volatile alkali; for in either case it must evolve its elastic fluid, which by supposition it cannot do. Nothing remains to solve this difficulty but the ignition of the surrounding metal, by means of which the calx, in virtue of its superior attraction, seizes the phlogiston of the metal, which that substance, here as well as in other instances, is capable of losing without the eruption or absorption of any fluid whatever.

Whether

Whether this explanation be satisfactory or not I leave to the decision of the judicious.

(E) The stories told us by authors of the fulminating property of certain metals, particularly copper and silver, have not, I confess, been verified by my experiments; so they have either been silent upon some circumstances necessary in the operation, or perhaps have been deceived by the detonation of nitrum flammans, or some other accidental occurrence. It is not sufficient for the volatile alkali to adhere to the precipitate; for platina thrown down by this alkali retains a portion of the alkali very obstinately, but yet does not fulminate on exposure to fire. Besides the presence of volatile alkali, it seems to be necessary that the metallic calx should be reducible by a gentle heat, in order to decompose it: but every explosion is not to be derived from the same causes; nay, in this respect aurum fulminans, gun-powder, and pulvis fulminans, differ very much, though they agree in several particulars,

DISSERTATION XVIII.

OF

PLATINA.

§ I. *Introduction.*

D SCHEFFER was the first who properly examined the new metal which was lately found in America, and brought to us under the name of platina. In the year 1752 he investigated its properties, and demonstrated that in perfection it approached to gold, and therefore gave it the name of white gold: after him many experienced chemists, with laudable industry, have laboured in the accurate examination of this substance; so that we may say with justice, that there are few of the metals, though known and used for eighteen centuries and upwards, which have undergone so accurate an investigation, by means of the most

most acute experiments; notwithstanding this, however, many circumstances occur to an enquirer which are still obscure, and not sufficiently elucidated by experiment, and hence have arisen many dissensions. Some of these points I hope I shall be able to elucidate, especially as I am in possession of a sufficient quantity of platina, by the generosity of the Baron Claudius Alstromer, who had brought it with him upon his return from Spain.

§ II. *Platina precipitated by Means of vegetable Alkali.*

This new metal, dissolved in aqua regia, exhibits, upon precipitation, many peculiar properties worthy of accurate examination. — We shall begin by the precipitate occasioned by vegetable alkali.

(A) Aqua regis, composed of nitrous and marine acid, attacks platina, exhibiting a solution at first yellow, but which when further loaded grows red, and the colour grows the deeper as the solution is more loaded with the metal. Upon evaporation crystals are produced, of a deep red colour, frequently opaque, but sometimes pellucid, in general very small, irregular, and resembling angular grains, the real form of which I have not yet been able to discover.

(B) These crystals, washed and well dried, require far more water than gypsum

does to dissolve them by boiling. The solution is yellow, and separates some pale flocculi, which are probably martial: vegetable alkali does not disturb the solution, nay, the caustic lixivium of this alkali, when hot, does not dissolve the crystals, or at least attacks them very faintly, even although a digesting heat be applied, and the liquor evaporated to dryness. By this method the colour of the crystals is a little weakened, the aerated mineral alkali dissolved in water takes them up and grows yellow, yet it remains clear, and in many hours does not deposit any thing, but by evaporating to dryness it decomposes them.

(c) The solution (A) upon the addition of a little vegetable alkali, either aerated or caustic, immediately, or at least in a few minutes, deposits small ponderous red crystals, of a different nature from those mentioned in B; these are sometimes distinctly octaedral, and soluble in water; they are decomposed with difficulty by the mineral, but are not changed by the vegetable alkali.

But if the alkaline salt be added in larger quantity, the superfluous acid being saturated, there is separated a yellow spongy powder insoluble in water, which exhibits a calx of platina.

The clear solution (A) reduced so far by evaporation, that the remaining liquor consisted only of a few drops, upon the addition of the alkali exhibited the same phenomena

nomena as mentioned above, except that the crystalline powder was of a deeper yellow.

(D) Instead of the vegetable alkali, let the same, saturated with an acid, either vitriolic, nitrous, marine, or acetous, be employed; nevertheless, the red crystalline molecules appear; but by this method the whole of the platina cannot be separated, as in the foregoing paragraph (C); for the solution retains a deep yellow colour, however abundantly these salts be added, nor does any genuine calx of platina fall, except upon the addition of an alkali; for which purpose either the mineral or vegetable will serve.

(E) I took the same weight of platina as in A, and tried it with an equal bulk of menstruum, consisting wholly of nitrous acid; to which was added of common salt four times the weight of the metal: this nitrous acid was taken out of the same bottle as in A; in a digesting heat all the platina was dissolved; the solution was red, but more dilute than that in A; a yellow powder floated on the surface, but at the bottom a larger quantity of the same was found.

The clear solution, upon the addition of the smallest quantity of vegetable alkali, deposited a copious yellow powder, which yet was soluble in a sufficient quantity of water. The neutral salts, with a vegetable alkaline base, also precipitated a similar powder more slowly

slowly and more crystalline; but the mineral alkali, though employed in fifty times the quantity of the vegetable alkali, does not at all disturb the solution, the abundant acid not being yet saturated.

The powder collected at the bottom was totally soluble in water, and in its properties agrees with the crystalline powder spontaneously separated in B, but is of a yellow colour.

(F) I repeated the experiment with the same quantities, but instead of the nitrous acid and sea-salt, I used the marine acid and nitre, well depurated. In this experiment the platina yielded a solution of a golden colour, together with a greenish powder, mostly granulated, the more subtil part of which floated on the surface.

The clear solution did not deposit any thing upon the addition of vegetable alkali, until all the superfluous acid was saturated, but then yielded a metallic calx insoluble in water.

The green powder is wholly soluble in a sufficient quantity of water, and agrees, as to its properties, with the crystalline powder occasioned by the vegetable alkali in c and d.

(G) Platina precipitated from aqua regia by a sufficient quantity of mineral alkali, well washed, and dissolved in marine acid, upon the addition of vegetable alkali immediately lets fall a crystalline powder; which
is

is also the case with nitre and other neutral salts, whose basis is the vegetable alkali. I employed the additaments, especially the neutral, dry, or at least well saturated solutions.

(H) The case is the same with calx of platina dissolved in vitriolic acid.

(I) The precipitate of platina is taken up also in the same way by nitrous acid freed from all admixture of the marine; but this nitrous solution exhibits different properties with the vegetable alkali from those of the muriatic solution in G; for I could not obtain a distinct saline precipitate, without the addition of marine acid.

(K) That which I have now affirmed of the calx of platina, is also true of the precipitate occasioned by vegetable alkali, after the deposition of the saline powder (C).

(L) Upon comparing these experiments it will readily appear, 1st, That the precipitate which is first thrown down, on the addition of vegetable alkali to solutions of platina, is a saline substance, and different from the calx of this metal (C): 2d, That this saline precipitate is composed of calcined platina, marine acid, and vegetable alkali (D E F G and I): 3d, That by means of vitriolic acid a precipitate analogous to this may be obtained, composed of calcined platina and vegetable alkali, joined to vitriolic acid (H): 4th, That the whole solution of platina cannot be precipitated in the form

of

of a triple salt by the vegetable alkali, either disengaged, or otherwise; but that a determined limit takes place, upon passing which it yields a metallic calx in the usual way, like other metals.

§ III. *Platina precipitated by Means of the Mineral Alkali.*

The most celebrated chemist of the age, Mr. Margraaf, denies that a solution of platina can be precipitated by mineral alkali, which Dr. Lewis confirms on repeating the experiment. Now, as none of the metals adhere to acids with so much force as to refuse quitting them on the addition of mineral alkali, platina would form a very singular exception; I therefore thought this circumstance worthy of particular examination.

(A) I tried the common solution of platina with a solution of mineral alkali; each drop, on falling in, excited a violent effervescence, but no precipitate appeared. I still continued, however, to drop in the alkali, and at length the solution began to grow turbid, and a spongy yellow powder was precipitated, consisting of a genuine calx of platina.

I afterwards effected the same more quickly, by employing the mineral alkali dry, and spontaneously calcined.

(B) In

(B) In order the better to determine the different efficacies of the fixed alkalis, I divided a solution of platina, as yet very acid, into two equal parts ; to one of them I added small portions of the vegetable, and to the other an equal weight of pieces of mineral alkali : between the addition of every two pieces I waited five minutes, till the effervescence had ceased. After the third addition, I observed small crystals appearing in the first, partly on the surface, partly on the bottom ; while at the same time no separation of calcined platina appeared in the latter, until after the addition of fifty-six times the quantity of the vegetable alkali ; the difference was, however, still greater than at first appears from this experiment ; for the vegetable alkali was crystallized, and therefore charged with the water necessary to its crystalline form ; whereas the mineral alkali was spontaneously calcined ; and although in equal weights of these two alkalis, the pure alkaline parts are as 3 to 2, yet 3 parts of vegetable alkali saturated only 1,71 of this aqua regia, while 2 of the mineral alkali took up about 2,6.

A difference so great as this, together with the then undiscovered saline nature of the precipitate first thrown down by the vegetable alkali, undoubtedly contributed to deceive these experienced and deservedly admired chemists ; a circumstance which is by no means wonderful.

(c) In

(c) In respect of precipitation, therefore, the mineral alkali suffers no impeachment, but rather the vegetable exhibits a very singular habitude with regard to dissolved platina, which it does not possess with any other metal.

§ IV. *Platina precipitated by Means of volatile Alkali.*

Dr. Lewis was the first who shewed that platina may be precipitated by sal ammoniac; this is a singular phænomenon, which we should by no means expect from a neutral salt, and which I have never yet seen explained.—The following observations are intended to illustrate this process.

(A) The volatile alkali, whether mild or caustic, precipitates platina in the same way as described § II. c; at first it throws down the metal in a saline form; and, although the grains be small, yet they are of a crystalline shape; which upon examination is sometimes found to be distinctly octaedral.

Their colour varies according to the intensity of the solution; when red, it deposits red crystals; and when more dilute, no other than yellow. After the superabundant acid has been saturated, the same alkali precipitates the platina truly calcined.

(B) The saline precipitate, though slowly taken up by water, yet if the quantity of water

water be sufficient is totally dissolved, and may by evaporation be reduced to more regular crystals.

The mineral alkali dissolves these crystals; but scarcely any signs of decomposition appear, unless the yellow solution, evaporated to dryness, be again dissolved in water; for then the metallic calx rests at the bottom, and the solution wants the yellow colour. The vegetable alkali has scarcely any effect in this way, for after repeated exsiccation, the solution remains clear and yellow; but here it appears very probable, that this alkali takes the place of the volatile, for in larger quantities, and especially when the caustic vegetable alkali is employed, the expulsion of the volatile alkali is in some degree manifest by the smell.

(c) The volatile alkali, saturated with any acid, throws down a similar saline precipitate, at least it produces the effect, whether it be joined with vitriolic, nitrous, or marine acids; but these neutral salts precipitate only a determined quantity of platina; for, after the cessation of their effect, the remaining liquor, upon the addition of vegetable or volatile alkali, lets fall a pure calx.

(d) The calx of platina, precipitated by mineral alkali, and then dissolved in any simple acid, as vitriolic, nitrous, or marine, exhibits nearly the same phenomena with

volatile alkali, whether disengaged or otherwise, as it does with the vegetable alkali.

(E) Upon considering these experiments, therefore, we may conclude, that platina, dissolved in acids, forms at first, as well with the volatile as with the vegetable alkali, a triple salt, which is difficultly soluble, and therefore almost always falls in the manner of a precipitate, unless the quantity of water be more abundant than ordinary.

§ v. *Platina precipitated by Means of Lime.*

(A) Lime, whether aerated or caustic, precipitates platina in the same manner as the mineral alkali does, without any crystalline appearance.

(B) Upon the consideration of these phenomena, there appears a singular analogy between the vegetable and volatile alkalis, and between the mineral alkali and lime. A like agreement takes place between these substances in other instances. I shall mention one remarkable example:—alum, extracted from argillaceous matters, by means of vitriolic acid, sometimes cannot, without difficulty, be reduced to solid regular crystals; but by the addition of a small quantity of vegetable alkali this inconvenience may be remedied, and the volatile alkali produces the same effect. It may be suspected,

pected, that this is owing to the abstraction of superabundant acid ; but it cannot be done either by mineral alkali or lime, both of which are capable of saturating the acid ; besides, not only the vegetable and volatile alkalis assist the crystallization of alum when they are disengaged, but also when united with acid, which makes the resemblance complete. The matrixes of alum frequently contain the proper alkali, either naturally combined with them, or superadded in the roasting ; and hence it is seldom necessary, in the preparation of alum, to promote the crystallization by alkalis.

§ VI. *Difficulty with which Platina is fused.*

It is well established, that of all known metals platina is the most difficult of fusion ; for, in its perfect state, it is scarcely to be overcome, except in the focus of a burning mirror ; while mercury, on the contrary, finds sufficient heat in the coldest winter to preserve a fluid form ; but not long since, the celebrated Delisle discovered a method by which platina may be fused even by a common fire. Thus the precipitate obtained by sal ammoniac, exposed without additament to a most violent degree of heat in a blast-furnace, yields a polished metallic globule, which is sometimes sufficiently malleable. I have repeated the experiment with success ; but in order to obtain the regulus

in a malleable state, the quantity must be very small, and the heat very intense.

(A) I tried whether platina, precipitated by sal ammoniac, could be fused by the blow-pipe. In order to make a small portion remain on the charcoal, notwithstanding a violent blast, I added to it a little microcosmic salt in fusion, and in a few minutes obtained a polished globule, but so very small, that when beaten out it yielded a circular plate of only one line in diameter. I found means, by the addition of microcosmic salt, to reduce seven or eight of these planes into one mass, equal in bulk to the head of a common pin; and after beating this out, I once reduced it again to a globular form, still preserving its malleability, but could not fuse it again; for, being imperfectly fused, it broke under the hammer.

Borax is scarcely of any use in this operation, for it expands upon the coal together with the precipitate.

(B) The saline precipitate thrown down by volatile alkali, treated in the same manner, exhibits the same properties as the foregoing.

(C) I found so great resemblance between the precipitate occasioned by the volatile and by the vegetable alkali, that I should have concluded, that in this experiment they would prove to be similar; but I have often had occasion to see how

little analogy is to be confided in; I therefore made the experiment with the crystals obtained by vegetable alkali, and found my conjecture to be just.

(D) The crystals obtained by spontaneous evaporation (§ II. B) after completely drying, when added to the microcosmic salt in fusion, decrepitate more violently than those obtained by means of the alkaline salt (§ II. C; and IV. A). Somewhat, however, remains in the fixed mass, which is not unfrequently reduced upon its surface, yielding a pellicle of a silver colour; but I have not hitherto been able to reduce it to a globule. Thus far I have advanced, namely, to obtain the platina collected together within the salt, in a white mass of an irregular form; but the particles of this spongy mass were separable by mechanical force. This is the case with the calxes of platina, by whatever alkali they are precipitated (§ III. A; II. C; and IV. A); therefore it seems very probable, that the principle which disposes to fusion is supplied by the vegetable, and also by the volatile alkali.

§ VII. *Properties of depurated Platina.*

By the method now described, I obtained several very beautiful pieces of regulus; they were, it is true, exceeding small, but wonderfully malleable; and were freed from iron by repeated fusion with microcosmic

salt, more completely than by any other method hitherto known. It is proper to observe, that the crude platina was selected, and repeatedly boiled in marine acid, until the menstruum could not extract any more iron. By this process 0,05 were separated, the remaining part of the iron being doubtless so enveloped by the particles of platina that the boiling acid cannot have access to them. This platina, after washing, was dissolved in aqua regia freed from all iron, and then precipitated by the purest sal ammoniac. I shall therefore describe the qualities of the regulus obtained from this precipitate.

(A) Its colour is that of the purest silver.

(B) The very small globules are wonderfully malleable, but when many of these are collected together they can scarcely be so perfectly fused as to preserve the same degree of malleability.

(C) A magnet, though of great power, does not act upon them in the least, nor is the most delicate magnetic needle affected by them.

(D) They cannot be dissolved by any simple menstruum, except the dephlogisticated marine acid.

(E) Aqua regia, composed of the acids mixed, dissolves them, is yellow at first, and, when more saturated, red; on evaporation the solution yields shapeless crystalline grains, though I must confess, that in the place

place of these I have sometimes obtained nothing more than a saline mass.

(F) Their habits with alkalis, whether disengaged or saturated with acids, are the same as above described.

(G) The phlogisticated alkali, well saturated, and freed from the small portion of Prussian blue which it dissolves, occasions no precipitation, but the colour of the solution is rendered darker. This lixivium therefore dissolves platina, as well as some other metals. Not the smallest vestige of Prussian blue appears, which yet is evidently seen upon the addition of a portion of martial vitriol, amounting to only 0,001 of the platina contained in the solution, although 0,001 of martial vitriol contains only 0,00023 of iron.

§ VIII. *Whether Platina be a Metal distinct from all others.*

Although many of the moderns give platina a place among the metals, yet there are some naturalists of high reputation who consider it as nothing more than a mixture of gold and iron. We shall not here consider the arguments on both sides, but rest entirely upon the conclusions which follow clearly from the preceding experiments.

(A) As to iron, there is no doubt of its presence in platina, as is evidently shewn both by the magnet and the phlogisticated

lixivium : but whoever examines the metals accurately will find that they never occur in a perfectly pure state. Gold is contaminated more or less with silver, copper, or iron ; silver with copper and arsenic ; copper with iron, and that generally in such a quantity as to be discernible, but sometimes in such small portions as to be concealed ; nickel contains cobalt ; and so on. Let us now suppose that native platina is never found without iron ; yet it does not follow from thence that iron enters into it as one of its constituent principles.

(B) This iron may be artificially separated, or at least so much diminished as not to be in the smallest degree sensible, either to the magnet or the phlogisticated lixivium (§ VII.) With what appearance of probability then can it be said, that in depurated platina (which in 100,000 parts is supposed to contain 99,977 of gold) the nature and distinguishing properties can be so changeable as that a smaller quantity than 0,00023 of iron (§ VII. G.) shall operate so as to conceal the properties of both the ingredients ?

(c) I have long wished to get a piece of platina entirely crude, and unchanged by art ; for not only is iron supposed to be a principle of this metal, but it is asserted to be magnetic : it is known that grains of platina are found mixed with gold in the bowels of the earth, and that the gold is freed from

from them in iron mills by means of mercury ; may not the magnetism therefore be occasioned by the iron which adheres during this operation, as we know that iron receives that property by percussion and other means ? — besides, a suitable situation, long continued, also generates that quantity ; and perhaps to this cause may the magnetism be owing, if it actually does take place in crude platina ; if not, it must be entirely attributed to art.

In the year 1774 two Spaniards who had come to Upsal, from America, presented me with two sorts of platina, one of which had been washed with mercury, in order to separate the gold ; the other rude, which they asserted had never been exposed to amalgamation. This latter was to me a very acceptable present ; but my pleasure soon vanished, for a few ounces of it, exposed to fire in a glass cucurbit, sent forth mercurial vapours, which formed into globules on the neck of the vessel. As platina is mixed with particles of gold, there is very little probability that it ever comes to Europe pure : it may happen also that it repeatedly undergoes that operation, for even such as is brought to Europe yields grains of gold : when once deprived of the gold it is thrown out ; and this it most probably is which, after a series of years, is considered as pure.

DISSERTATION XIX.

OF THE

WHITE ORES OF IRON.

§ 1. *An accurate Knowledge of Ores necessary to the proper Treatment of them.*

OUR omnipotent Creator has provided for the use of man an inexhaustible store of natural bodies, which are to be found in the external covering of the globe; some of these we have accidentally learned to employ to our advantage, others we have been urged by necessity to seek; and by slow degrees, and after many trials, we have discovered the proper treatment of them: but the greatest number we still neglect as useless, being ignorant of their value.

It

It is obvious, that in proportion as men become more perfectly acquainted with the virtues, qualities, and composition of bodies, the more perfectly and easily will they be able to apply them to their advantage and convenience. Upon that particular, therefore, should our chief care be employed, for a proper acquaintance with the stores of nature will certainly be followed by the application of them to use: nevertheless, so provident has nature been against human ignorance and sloth, that the rudest labour is not without signal advantage: thus in the darker ages we find the richest minerals used as tributes, a circumstance which naturally followed the discovery of them; yet they were not valued in proportion to their goodness. When, by the experience of ages, the various qualities of these bodies were discovered, the foundation of metallurgy began to be laid; and in proportion as the superior skill of men now enables them to obtain more metal from poorer veins, nature seems to have diminished the former superabundance of these productions. The chemical knowledge of the present times would be too much enriched, if the former abundance subsisted; and on the other hand, the rude and unskilful attempts of the first inventors would be entirely useless, had they been cramped by the scarcity which is now found to take place.

§ II. *Physical Qualities of the white Ores of Iron.*

These ores have received divers denominations, from the singular heat with which they are accompanied. In Germany they are called *stahlstein* or *stahlertz* (as the iron got from them could be changed into excellent steel) as also *weisse*, *eisenspat*, *pflintz*, and other names : in France they are called *mines de fer spatique*, although it must be confessed that they are not always spathous ; and that moreover many which are of a spathous texture, and loaded with iron, do not belong to this class.

(A) The texture of these minerals is almost the same as that of the calcareous stone, yet it is rarely found compact, and composed of impalpable particles ; it is sometimes squamous, sometimes granulated with small distinct particles, some of them shining, but in general it is spathous. We do not speak of them here in their complete and perfect state ; for the figure of their parts is more or less destroyed by spontaneous calcination, nay, the whole mass is at length resolved into a powder : sometimes it is found stalactitic, fistulous, and ramous, or even cellular, nay sometimes germinating like moss.

(B) They are sometimes, but very seldom, so hard as to strike fire with steel ; but
though

though (when found mixed with flint, and newly dug up) they are of this kind, yet they soon lose that property: in other respects, when perfect, they generally resemble calcareous stone, unless when exposed to the air for some time, by which the union of their parts is gradually diminished.

(c) The colour is white, but the surface which comes in contact with the air grows gradually brown, or even blackish; yet so long as the iron, which is converted into an ochre, remains in them, they have a ferruginous hue; but though the surface is thus changed, the internal parts remain the same, and upon filing or breaking exhibit the natural colour.

This change is effected by the air, not upon the iron, as is commonly believed, but upon the white calx of the manganese, which is dephlogisticated by the surrounding atmosphere; a circumstance which it is sufficient here to mention, as it will be more accurately explained hereafter (§ VII. G).

(D) The specific gravity of the ore, when perfect, varies between 3,640 and 3,810, and is diminished according to the degree of calcination. That ore, whose particles scarcely cohere, but are quite separated, is from 2,5 to 2,9; but that which is not perfectly corroded, from 3,3 to 3,6.

(E) The ore, whether perfect or calcined, is rarely attracted by the magnet, though the

the martial part sometimes amounts to nearly half the weight.

§ III. *Situation of these Ores in Mountains.*

The white ores of iron are found, but very sparingly, in Sweden: Suartberger, (*i. e.* Black Mountain) near Schifshytta, in Dalekarlia, has its name from its surface, which is grown black by calcination. This mountain is high, and naked upon the summit, which is crossed by a broad calcareous vein, with shining particles of spar, and a white ore of iron, together with galena, pseudo galena, and black ore of iron, pyrites, schoerl, and garnet intermixed. In the old mines at Hællefors, or the eastern mines, the rock itself appears to consist of a white ore of iron. It is sometimes found also in other mountains, but generally either in small quantity or very poor in metal.

Germany is rich in these ores: many mountains about Smalkald contain them: in that which is called Stahlberger a broad vein, almost horizontal, occurs from twenty-five to thirty fathom thick; this consists of an irregular spar, in which are dispersed quartz, and pieces of the ore, which are found of a better quality, in proportion as they are more deeply seated. The pendent side, which is uppermost, is composed of a sandy stone from nine to twenty fathom high, but the lower, which is the foundation,

tion, is margaceous, and is found more indurated towards the lower parts, and at the very lowest is extruded by a blue mica; the sides scarcely cohere to the vein.

In Nauffavia the whole mountain seems to consist of a yellowish ore of iron, certain veins of which are accompanied with copper, others with hæmatites.

In Upper Stiria, at Eifenarg, is situated Arzberg, in circuit 6,000 fathoms, in diameter 900, and in height 450: it is described by some as irregularly accumulated and concreted, and as consisting of masses of quartz, charged with argillaceous earth and white ore of iron; but others contend that the ore is there found not only in heaps but also in various veins.

France and Spain produce great quantities of these ores.

The examples above cited seem to indicate that the white ores of iron are found sometimes in heaps, but that they also form sometimes veins, sometimes strata, and sometimes whole mountains. I have never found that they contained any organized bodies, a mark by which the most ancient productions of the earth have been distinguished.

§ IV. *Properties of these Ores examined by the Blow-Pipe.*

Experiments, with this instrument, although made upon small pieces, yet in general

neral shew the nature of the substance examined with considerable certainty, and point out the method of treatment proper for larger quantities; therefore it is that I am of opinion we should begin our experiments in that way.

(A) The white ore of iron, exposed to the flame, at first is apt to decrepitate, and that the more violently, as it is of a more crystalline texture; so that that which is of a dense texture, and whose particles are scarcely discernible, decrepitates little or none: a certain degree of spontaneous calcination also overpowers this decrepitating quality.

Another, and a more remarkable effect of the fire, is a sudden change of colour: the whiteness soon changes to a brown, which quickly gives place to a blackness, which cannot be discharged even by violent and long-continued heat.

A piece of the ore, when blackened by the fire, is always attracted by the magnet, although, as is frequently the case, it had not been obedient to it before.

But the ore alone is not fused without great difficulty, though the fire be violent and long continued. Upon fusion it again eludes the force of the magnet.

(B) A small portion, added to a globule of microcosmic salt in fusion, is dissolved with more or less effervescence, and imparts an iron colour, that is, a greenish or a yellowish

lowish brown, which upon cooling grows weak, and at length entirely vanishes.

When the globule, after cooling, is again softened, not by the interior and blue cone of flame, but by the exterior and less defined part, a red colour is generated, which also vanishes upon cooling; this is made more distinct by the addition of a small piece of nitre, but upon cooling is weakened. Fusion by the blue cone, continued for some time, extinguishes the redness, so that the iron tinge appears: in this way the red colour may be many times alternately discharged and renewed.

When the globule is supersaturated with the salt, upon cooling it grows opaque, white or black, according to the different quantities of the calx and the iron; and in the latter case it sometimes possesses a metallic splendor.

A variety in the proportion of the principles occasions great changes in the phenomena;—thus the original effervescence is both more visible and more durable when the calx abounds. When the iron is deficient, its colour can sometimes scarcely be discerned; and when the quantity of manganese is very small, and that of iron large, the redness scarcely appears without the addition of the nitre.

(c) The white ore of iron is dissolved in the same manner by borax, *viz.* the effervescence

vescence is more or less conspicuous, according to the quantity of calx.

The vitreous globule frequently acquires an obscure reddish yellow colour, which yet, upon the continued application of the blue cone, is totally destroyed, the martial tinge remaining: but by nitre, or by softening alone, which is effected by the exterior cone, the hyacinthine colour above mentioned again appears.—These changes may be produced at pleasure.

By supersaturation the globule becomes opaque, black or white.

(D) The mineral alkali fused in a silver spoon takes up the ore with an effervescence more or less remarkable, yet divides it but little, nor is the milky globule rendered brown, unless by a larger addition, and a longer continued fire, and then it grows black.

(E) These experiments shew that the ore contains lime somewhat siliceous, iron, and manganese; and although these ores may appear to many of little consequence, yet they have discovered to me a new metal, which by other means could not be discovered. The properties of manganese, hereafter explained (§ VII.) will illustrate this assertion more fully.

§ v. *Properties of these Ores examined by the Via Sicca.*

(A) 100 parts finely powdered, and exposed upon a tile to the fire, grow quickly black, and become obedient to the magnet; in this experiment sometimes red spots appear here and there, occasioned by the admixture of pyrites. An heat of two or three hours occasions a loss of weight different according to the variety of the ore; the loss is at the least 15, and at the most 40 assay pounds: by a longer continuance of the heat the loss is not increased; nor does the black colour disappear, nor are any signs of fusion to be observed.

On calcination, no smell is perceptible, unless there be an admixture of some pyritous particles.

When the pieces are sufficiently roasted, and after cooling put into water, they often generate heat, and form a sort of lime-water.

(B) In order to learn the nature of the substance expelled by fire, 100 of the pulverized ore was put into a small retort, to which was adapted a receiver, which by a lateral tube conducted the elastic fluid into a glass vessel full of water, and inverted; the fire was then gradually increased, until the bottom of the retort began to grow soft; in the mean time a small quantity of liquor

was found in the retort, but in the inverted glass a large quantity of elastic fluid.

The liquor in the receiver was found of an aqueous nature, but for the most part so small in bulk as scarcely to be collected, seldom so much as 0,1, and never exceeding 0,2. The ore, when perfect and crystallized, usually yields a little more water than when broken down by spontaneous calcination, or when naturally denser.

The elastic fluid, when confined by mercury, sometimes occupied 30 cubic inches, but was generally less: on examining this it was found to be mostly absorbed by water, and to communicate to it a pungent acidulous taste, together with the property of making the tincture of turnsole red. It precipitated lime-water, extinguished flame, and destroyed animal life: these properties shew it to be the aerial acid; the portion which remains and refuses to unite with water, is common air, which doubtless was at first contained in the retort. When the aerial acid is separated by water, a species of deflagration takes place; yet it should be observed that inflammable air is almost always absent.

The black residuum in the retort, though it be not ignited, is sometimes attracted by the magnet.

(c) This ore, pulverized and strewn upon hot coals, exhibits a kind of phosphoric appearance, which is light and momentary; but

but when exposed to fire alone in a close crucible, it quickly liquefies, and perforates the bottom. This effect is occasioned by the calcareous earth in the ore dissolving the siliceous and argillaceous earth of the vessel: these three, when mixed, easily flow, and besides, the calxes, both of iron and manganese, which are here present, promote the vitrification very much.

(D) The powder, let fall into nitre, fused and ignited, shews no distinct detonation, but a crackling is heard.

(E) I have attempted the reduction of these ores by many different ways, but it is only necessary to mention those which are particularly useful in the extraction of iron.

The first, most simple, and in many cases the best, is this: — the bottom of a crucible is covered, to the thickness of about half an inch, with powdered charcoal; this powder is moistened with water, mixed with a small portion of argillaceous earth, so that upon compression the particles may the better adhere together, and to the crucible; the sides are lined in the same way, but thinly. The superficies of the stratum ought to be rather concave, so as to receive in the lower part 100 of pulverized ore, covered with calcined borax; for that which still retains the water of crystallization upon boiling, disperses many particles of the ore; finally, another crucible is to be inverted,

verted, and luted on, and the whole exposed to a proper fire.

The second method is this:—100 of the ore, mixed with an equal weight of mineral fluor, and half of apyrous clay, is put into a crucible, prepared after the manner above described, and treated in the same way, but without the addition of borax.

The third is directed by D. Scheffer:—to 1 part of ore are added 1 of tartar, 1 of charcoal-dust, 1 of glass, 1 of white, and 2 of black flux; the mixture is put into a crucible prepared without lining, and shut as before.

The fourth, which has been long in use, is described by Snack, and is preferred to all others by D. A. Swab, although it is very complex:—to 100 of the ore are added an equal weight, or 100 of sal ammoniac, 100 of tartar, 100 of glass gall, 50 of borax, 50 of charcoal-dust, and of black flux 200; the mixture, put into an unprepared crucible, is covered with common salt, and, being covered, exposed to the fire.

In order to compare these different methods, with respect to the white ore of iron, I treated different portions of it according to all the different methods, and that without previous calcination, which in this instance is of no effect. That which I tried was a spathous frustum, not yet injured by calcination, brought from Eisenartz, in Upper Stiria:

Of this 100, according to the first method, yielded of a regulus nearly of the splendor of silver	lb. 42
According to the second, of a regulus of an ash colour	39
By the third, a regulus of an ash colour, but nearly crystallized on the surface	29½
By the fourth, of a regulus almost white and splendid	36

I found nearly the same progression to hold with the ore of Nassau, and with the other ores, examined in the same way: in general the weight of the regulus never attains to 50, but is often 30, 20, 10, nay even sometimes no more than 2, though the ore has been made black by roasting, and is attracted by the magnet; but hereafter it will be demonstrated that the blackness by fire is not occasioned by the iron, but by manganese. The purest calcareous stones are seldom entirely without iron. The clearest Iceland spar grows red by long calcination; and even by the humid way yields its metal to phlogisticated alkali.

The ores which are so poor as not to yield a regulus without difficulty, are usually brought to that state by a small quantity of white arsenic, or rather of litharge; for by this method the scoria is made thinner, and the small globules permitted to subside and collect.

§ VI. *Properties of these Ores, examined by the humid Way.*

(A) The white ores of iron effervesce indeed with acids; but in general more weakly than the calcareous stones; and sometimes no motion is observed, unless pulverization and heat be both employed. That calcareous earth is present will appear from what follows; but the reason why it only effervesces slowly, is to be sought partly in its proportion, and partly in its intimate connection with the other principles.

(B) All those acids which are usually called mineral dissolve this ore, if it be well pulverized, and a due degree of heat applied. The solution made by vitriolic or marine acid is generally of a yellow green; that by the nitrous of a red or yellow brown; the marine acid dissolves it sooner than the rest; these colours vary a little, in proportion to the quantity of metallic parts. Sometimes a brown redness at first appears, which then vanishes, but sometimes persists, unless sugar, or some substance rich in phlogiston, be added.

Almost always somewhat remains undissolved, which yet, upon examination, appears to be of a different nature. I have frequently seen grains of schoerl, zeolith, quartz, mica, nay fibres of asbestos intermixed: but these are foreign matters, which,

which, although they sometimes form above 0,2 of the mass, yet are not a necessary component part of the ore.

The solution made by vitriolic acid, upon evaporation yields green martial crystals; and that made in marine acid, without heat, sometimes by spontaneous evaporation concretes into spathaceous forms, composed of hollow pyramids.

(c) During the solution an elastic vapour escapes, which, when extricated by vitriolic or marine acid, is not inflammable, even although the crude ore be attracted by the magnet.

The quantity of water is easily discovered by performing the operation in a large bottle, closed so as to give exit to the elastic fluid, but not to the moisture; for the diminution of weight in this case indicates only the volatile aerial fluid, whereas the loss suffered during calcination shews the weight both of the elastic fluid and of the water.

(d) As the various qualities above mentioned indicate the presence of lime, I attempted to separate it in the following way:—let a portion of the pulverized and calcined ore weighed, be put into diluted nitrous acid, and let the mixture be shaken for a quarter of an hour; after which let the powder be collected on a filter, and the clear liquor precipitated with aerated fixed alkali: by this method a white sediment was ob-

tained, which upon examination shewed all the properties of lime. I employed the calcined mineral, and the nitrous acid, lest any thing metallic should be taken up during the short agitation, otherwise the end might be answered by the marine acid; but then it is necessary, in evaporating the solution to dryness, to expose it to a more intense heat, that the dissolved metal may be spoiled of its menstruum, for the lime retains the menstruum more obstinately; hence, after this operation, the salited lime may be elixated from the residuum by water, and precipitated by an alkali.

The weight of lime varies much; in some ores I found a few hundredths; in the spathaceous kind about 0,1 consists of lime, in others 0,5, but it is never entirely wanting.

(E) Into a solution of the ore made with the purest marine acid, I poured a few drops of solution of terra ponderosa in the same menstruum, but the transparency was not in the least disturbed; from whence I conclude, that there is no vitriolic acid present.

(F) The same is true of the marine acid; for I examined the small portion of water expelled solely by heat in the distillation (§ v. B), and could not, even by paper tinged with turnsole, discover any traces of an acid: I also poured concentrated vitriolic acid upon the powdered ore in a retort, and into the receiver a small quantity of distilled water,

water, as water very greedily attracts the marine acid in a state of vapour; but neither by the smell, by any visible vapour, nor by precipitants, could I discover the smallest signs of a mineral acid, unless the heat was increased to such a degree as to force over some of the vitriolic acid. The water in the receiver was not at all disturbed by solution of silver, although, upon touching it with the end of a glass rod wet with marine acid, the silver was immediately precipitated, and a white sediment separated.

I conclude therefore with reason, that the vitriolic and marine acids, if they sometimes happen to be present, do not belong to the proper composition of the ore; and, in fact, how could the aerial acid exist together with these, being easily expelled by either of them?—and how could the marine acid, which with lime and iron forms deliquescent salts, in this case form with them an ore which not only remains dry in the open air, but even undergoes spontaneous calcination?

§ VII. *Principal Properties of Manganese.*

I have hitherto frequently named manganese, and mentioned several circumstances which cannot be properly understood without previously considering its nature. It is necessary therefore, before we proceed further, to describe the principal properties of
this

this substance, so far as they have hitherto been discovered.

(A) The mineral substance which is called black, or glass-makers, magnesia, is scarcely any thing more than the calx of a new metal.

It is many years since I began to suspect that some metal, different from all those formerly known, lay concealed in magnesium, being partly led to this opinion by the specific gravity, partly by its property of tinging glass, and partly by its separating from menstrua on the addition of phlogisticated alkali, a circumstance which takes place with all the metals, but not with any earth. In the mean time I attempted the reduction of it in various ways, but in vain; for either the whole mass ran into scoriæ, or I obtained only discrete sphaerical atoms, so much loaded with iron as to be magnetic. On account of its being so difficult of fusion, I at first imagined it had some affinity with platina: at length Mr. Gahn, without knowing any thing of my experiments, succeeded in obtaining larger pieces of regulus by means of a most intense heat; and Mr. Scheele, in 1774, published several curious facts relating to manganese.—The principal things resulting from the experiments of these gentlemen, and from my own, shall be the subject of the following pages.

(B) The reduction is effected in the following way :—a certain quantity of manganese, formed with oil or water into a ball, is put into a crucible prepared with charcoal-dust, as before described (§ v. E), the empty space is then filled up with charcoal-dust; another crucible is inverted by way of cover, and luted, and the whole apparatus exposed to the most intense heat which the laboratory can produce, for an hour, or more if necessary. The vessels being cooled and emptied, a regulus is formed, sometimes consisting of many pieces, which, collected, in some cases amount to 0,3 of the manganese.

If the fire be weaker than necessary, either no reduction takes place, or the metallic particles are discrete, not being so fused as to run properly together. If during the operation the crucible falls, so that the metal shall touch the naked side of the vessel, vitrification is inevitable.

(c) The metal obtained, which I call manganese, is about the specific gravity 6,850.

The surface is generally brown, and the larger pieces of regulus are scarce ever found globular, but knotty and irregular, which, no doubt, is owing to the difficulty of fusion, in which it seems to exceed even forged iron.

Being harder than iron, it breaks under the hammer: the fracture is irregular and rough,

rough, with a sort of whitish metallic splendor, which soon spontaneously grows brown : even the smaller pieces are not magnetic ; but the powder is generally obedient to the magnet, though the admixture of iron be avoided with all possible care.

Some small pieces, exposed to the fire in an Hessian crucible, in a blast-furnace, and kept there for twenty minutes, yielded a yellowish brown glass, and a small globule of iron. Here a remarkable difference between the two metals is observed, the manganese vitrifies, the iron persists, and is formed into a regulus.

The regulus, when well fused, generally persists in a dry place, but sometimes undergoes spontaneous calcination, and falls into a brownish black powder, which is found somewhat heavier than the perfect metal ; yet, when fresh, contains so much phlogiston as to produce inflammable air, on solution in vitriolic acid : this phlogiston it loses by time. The cause of this spontaneous resolution is not yet sufficiently explained ; but it appears very probable, that, on account of the weakness of the fire, the particles sometimes coalesce so imperfectly, that when the dephlogistication again begins, they easily lose their mutual connection : moisture, but particularly the access of aerial acid, assists this operation. A small piece, put into a dry bottle well corked, remained perfect for the space of six months, but afterwards,

afterwards, exposed to the open air of a chamber for two days, contracted a brownness on its surface, together with so much friability as to crumble between the fingers: the internal parts, however, retained an obscure metallic splendor, which disappeared in a few hours;—a piece more fully impregnated with iron resists the action of the air better.

(D) It melts readily with other metals, pure mercury excepted. Copper, united with a certain quantity of it, is extremely malleable; but upon the surface of this mixture, when polished, scarce any traces of the red colour are to be seen: this mixture sometimes by age produces a green efflorescence. Tin very easily unites with manganese; but zinc not without much difficulty, perhaps on account of its volatile and inflammable nature. White arsenic adheres to it, and by means of phlogiston reduces it to a metallic form.

(E) Manganese, calcined by fire, yields a blackish calx; but if the ignition be continued for twelve days it acquires a dark green colour; sometimes also it produces a white or a red calx, of both which we shall treat separately (G). The black calx retains a very small portion of phlogiston, but the white abounds with it so much that it is soluble in acids.

All these varieties, in a common crucible, by means of a sufficient degree of fire,
run

run into a yellowish red glass, which is pellucid, unless too great a degree of thickness renders it impervious to the rays of light.

The black calx of manganese by a peculiar energy, when mixed with other substances, attracts phlogiston, and exhibits several remarkable phenomena both by fire and solution; the chief of which we shall consider, beginning with those which occur in fusion.

(F) In order to discover the genuine habits of this substance, we must employ the blow-pipe; for, by means of this instrument, we can distinctly see all the successive changes occasioned by fire, from the beginning to the end.

Let a globule of microcosmic salt be fused upon the charcoal, and to it be added a small portion of the black calx; let this mixture be fused, by means of the interior blue flame, for a few minutes, and it will yield a bluish red pellucid glass; but if the quantity of calx be greater, it is of a rich red. Let it be again fused, but for a longer time, and we shall find the tinge totally destroyed. Let the globule, which is now colourless, be softened by the exterior flame, and the colour quickly returns, and may be again discharged by continued fusion. The smallest particle of nitre too, added to the glass, instantly restores the red colour; whereas sulphur, and the salts containing vitriolic acid,

acid; contribute to discharge it; as also do the metallic calxes, although these, in proper quantity, communicate each its own particular colour.

The glass globule, after being deprived of all colour, if fused in a silver spoon recovers its redness, which it retains notwithstanding a long continued fusion; inflammable additaments indeed extinguish the colour, but this is easily restored by fusion, nor can it again be discharged without a new addition.

These changes are agreeable to the eye, and of themselves very remarkable: upon considering the whole, it will readily appear that the cause of them is to be sought in the different quantities of phlogiston. Let us first examine the most simple case:—the globule of microcosmic salt fused, consists of the phosphoric acid only, partly saturated with mineral alkali; the disengaged part must therefore necessarily attract phlogiston from the ignited charcoal, which is again taken from it by the calx of the manganese: now this calx, by a certain degree of phlogiston, is reduced to such a state that it exhibits no tinge, almost in the same manner as the seven primitive colours when collected form the light, of day, at once white and transparent; now, whatever dephlogisticates the glass, deprived of this tinge, restores the redness, and this is effected by the nitre and the exterior flame.

These

These changes cannot take place in the silver spoon, because in this case the support does not supply any phlogiston, and therefore the colourless globule fused upon it is quickly deprived of the quantity of phlogiston it had before imbibed by the surrounding air—a loss which in this instance cannot be repaired, and therefore the globule continues red.

The additaments capable of destroying the colour are such as naturally contain phlogiston, such as sulphur and white arsenic; or at least such as easily take it up from the coal, such as gypsum and the other salts containing vitriolic acid, which thus readily run into sulphur. The metallic calxes too are of such a nature that they take phlogiston from burning charcoal, which they are immediately obliged to give up to the calx by means of its superior attraction.

The phenomena above described and explained also take place with borax, but with some difference: the colour with microcosmic salt is a bluish red; that with an equal quantity of borax, a yellowish red; but in both cases, by saturation, the same intense red is obtained. By fusion upon charcoal too the tinge is not destroyed so soon in the latter case, as borax attracts phlogiston with less force than the phosphoric acid does.

If a small quantity of calx of manganese be added to an alkali, either vegetable or mineral, fused in a silver spoon, and the fire
continued

continued for a few minutes, the globule soon becomes of a whitish blue; or, if any iron be present, it acquires a green tinge; by a larger quantity the colour is made more intense, even so far as to appear nearly black; but the mass fuses slowly, and, by being marked with spots, shews an unequal distribution. If to the fused mass be added either powder of charcoal or white arsenic, the calx of the manganese is phlogisticated and the colours perish; hence it appears why common crystalline glass grows red by the admixture of manganese; but if the alkaline salt prevails in it, it contracts a violet colour.

Nitre fused in the spoon flows about; but, added in small quantities to the alkaline salt, does not destroy its globular figure: in this case the colour is changed to green by the addition of a small quantity of calx of manganese, on account of the calcined iron present in the blue mass.

Many of these changes take place in a crucible, but not all: the red glass indeed, upon the addition of powdered charcoal, effervesces, and is deprived of its tinge; but the salts containing vitriolic acid, and the ignoble metallic calxes (except white arsenic, which easily yields its phlogiston) are of no effect; for although the vessel be red hot, neither the acid nor the calxes are thereby sufficiently loaded with phlogiston, and that portion which they naturally con-

tain, in this case is not separated; the contact of ignited coal is necessary.

These things being known, it will not be difficult to explain the use of manganese in the purification of glass; for the iron, which contaminates a vast number of bodies, adheres not only to the alkali, but to the siliceous earth of which the glass is composed. Now this metal, in order to enter the texture of glass, must be deprived of a certain quantity of phlogiston; the great quantity, however, of that principle with which it is capable of entering glass, produces a green colour in the same way, as by solution in acids (particularly the vitriolic) it produces a green vitriol: yet this salt, on being repeatedly dissolved, successively loses more and more of its phlogiston, for that reason grows pale, and at length is changed into a brownish red lixivium, which refuses to crystallize. If now so great a portion of manganese be added by fusion to glass, that on the one hand the phlogiston occasioning the green colour may be absorbed, and on the other by means of that phlogiston the calx be deprived of all colour, we shall have a glass colourless as water. Too great a proportion of manganese will impart its own colour, too small a one will leave a part of the original green in the glass: the latter excess, however, is preferable to the former, for a very slight degree of green is not perceptible in glass, unless when it is so hot

as

as almost to liquefy; and this, upon cooling, becomes again entirely invisible. But the iron, if too much dephlogisticated, communicates a yellow hue, which cannot be removed by the calx of manganese, but like the green when weak, can only be perceived in the glass while hot.

(G) The habits of manganese, examined by solution, confirm and illustrate the former experiments.

The vitriolic acid, even when concentrated, attacks manganese in its metallic form, but much better when diluted with double or triple the quantity of water: innumerable bubbles arise, which when collected are found to be inflammable. It is dissolved more slowly than iron, and leaves behind a black spongy substance, of the same figure as the metal; a smell is perceived similar to that occasioned by marine acid with iron: the solution is colourless, like pure water; and upon evaporation deposits very bitter spathous crystals, which are clear and colourless; but on the addition of alkali lets fall a white precipitate, which we formerly called the white calx of manganese, and is now to be more accurately examined.

It readily appears that this white calx of manganese, or more properly white aerated manganese, is not saturated with phlogiston, as it wants the reguline form; and that regulus of manganese during solution is deprived of a portion of its phlogiston, is the less
P 2 doubtful,

doubtful, as it is certain that during that process inflammable air is generated. This calx however retains precisely that quantity which is necessary to render it soluble in acids; and when this portion is dissipated by a white heat in open air, the calx grows black, and assumes the properties of the black calx, which we have been considering. Here we must observe, that a solution of manganese, much diluted, although with aerated alkali it affords a white precipitate, yet with the caustic alkali yields either at once a brown calx, or one which soon grows black in the open air; the reason is this:—aerated alkali yields the aerial acid to the falling calx, as is easily seen from the increase of weight, the effervescence of the precipitate with acids, and by pneumatic distillation: but in this case the acids fix the quantity of phlogiston necessary to solution, as is seen from hence, that the pure air contained in the atmosphere or in water, although extremely greedy of this principle, is yet in this case not able to separate it. But the white calx is easily taken up by all acids, and does not at all tinge the menstruum, unless it be sensibly mixed with iron: it follows naturally that the calx, precipitated by aerated alkali, should effervesce with acids; it is also to be observed, that the whiteness is the more perfect as the quantity of iron is less, as this foreign admixture fulfills the colour by a yellow or a brown.

We

We now proceed to the calcined black manganese: this, when either old or well calcined, is only taken up in small quantity by boiling in vitriolic acid; nevertheless, if the menstruum be added by successive portions, each of which renders a little soluble, it may be gradually saturated; and then, with aerated alkali, deposits a white calx: this seems to indicate that the calx, though dephlogisticated, yet possesses a small quantity of phlogiston, which is insufficient for the solution of the whole; notwithstanding which, the menstruum may be sufficiently saturated by such particles as lie next adjoining to it: these, by means of the acid, are capable of taking the necessary phlogiston from the more remote, if the number of them be sufficiently great to supply the quantity of phlogiston which is requisite for solution.

A singular translation we have already found to take place in the *via ficca*; and that the same is the case, the circumstances now to be related will put beyond all doubt:—the calx thus exhausted altogether rejects the vitriolic acid, unless some substance charged with phlogiston be added, which phlogiston is, by means of the acid, transferred to the calx; thus, upon the addition of sugar, honey, gum, or other suitable substances, the solution may be promoted and completed. Such of those substances as upon the abstraction of their phlogiston

perish (namely organic bodies) leave no other vestige of themselves in the solution than the phlogistication above mentioned. A similar effect is also produced by the metals, not only the imperfect, but, what is very extraordinary, even by gold itself: this especially takes place in the marine acid, but in all cases the metallic calxes are easily found in the solution. We have said that phlogiston is easily transferred, by means of the acids, to the black calx; and that this, when loaded with phlogiston in proper quantity, is dissolved; and this we have affirmed not without reason, for the calx, when boiled with sugar dissolved in water, is not supplied with phlogiston, nor is the sugar changed, but remains complete; and when it is separated by lotion the calx is found insoluble as before: but if an acid be also added, by its means the calx takes up quickly as much phlogiston as is necessary to make it soluble; nay, the phlogisticated vitriolic acid, when poured upon the calx, soon loses its smell, and dissolves it readily without any assistance.

Another method of solution has also been found out, which clearly shews the great attractive force this calx possesses with respect to phlogiston: thus, let the vitriolic acid be drawn off from the black calx several times with an heat approaching to ignition, in a glass vessel, either open or shut; after each operation let the soluble part be elixated with water, and at length nothing will

will remain : from whence then is derived the phlogiston necessary for solution?—I answer, from the decomposition of the matter of heat, which consists of pure air, joined to a determinate quantity of phlogiston. In order to shew that this is not bare conjecture, let the operation be performed in a close vessel to which is adapted a pneumatic apparatus ; and towards the close of the process pure air is copiously produced, which is extricated while the phlogiston is uniting with the calcined manganese. The calx is indeed of itself capable of decomposing the heat, but cannot be rendered soluble without acids : if the acid, a little diluted, be drawn off only to dryness from one half its weight of black calx, water is able to take up by elixation upwards of one fourth of the calx : this water is of a beautiful red, and on due evaporation yields crystals of the same colour ; this tinge indicates a deficiency of phlogiston, a deficiency which, as has been already said, may be supplied either by continuing the abstraction to ignition, or by some suitable phlogistic additaments.

We have hitherto only considered the white and the black calx ; it is proper now to bestow some attention upon the other varieties : that which is produced by the spontaneous calcination of the regulus is at first of a dusky colour, but in the open air grows more brown ; and in about fourteen days the weight is increased by 0,35, and is again

diminished a few hundredths, on exposure to heat. The humidity which had been attracted from the atmosphere being now expelled, this calx, in proportion as it is more newly made, and less exposed to fire, is the richer in phlogiston, and is the more quickly dissolved in vitriolic acid, with which it produces a bluish red colour: this elegant tincture, gently precipitated by means of aerated alkali, at length shews some red particles subsiding, which yet, collected on a filter, grow brown. It appears very probable that the red calx forms a sort of medium between the black and the white, being more soluble than one, and less soluble than the other; and that the colour indicates the imperfect state of the solution, for by the addition of sugar it is discharged in a few minutes: to this class, doubtless, belong the red and brown ores of manganese. The particles enveloped in transparent matrices afford very beautiful specimens, more or less pellucid: thus the red spathous ore which is got at Klapperud, in Dalia, is found filled with zeolith; so that a small piece, gradually put into an acid, is spoiled of the red calx, from the surface successively inwards to the center, though the original form and magnitude remain: the remainder, upon examination, is found totally siliceous, for the argillaceous and calcareous parts of the zeolith matrix are extracted by the acid, together with the calcined manganese.

Both

Both the red and the colourless calx of manganese are precipitated by a phlogisticated alkali of a whitish yellow, unless the iron be superabundant.

It has already been observed that the black calx of manganese grows green in a red heat, which was first remarked by the celebrated Rinman, upon making the experiment on a species of black calx of manganese, which must yet be particularly distinguished; for though it consists for the most part of a black calx, yet it contains a number of heterogeneous particles, such as calcareous and siliceous earth, and terra ponderosa, substances which are always mixed with the Swedish calx: this green calx is found concreted into loose grains, is made white by the vitriolic acid, and corroded into a subtile powder; but very little is dissolved, even by the addition of sugar, nor is a red tinge ever produced.

Having thus spoken pretty fully of the vitriolic acid, let us now briefly consider the other acids.

The nitrous acid dissolves the regulus with a certain effervescence, occasioned by the generation of nitrous air; yet a spongy, black, and friable body remains, resembling molybdæna in its properties, so far as the small quantity of the matter would permit experiments to be made. The other menstrua also exhibit a similar residuum; the solution is always brown, which is occasioned by the
iron

iron adhering to the manganese—it scarcely acquires a red colour : the white calx is very readily taken up by the acid, during which operation the aerial acid is extricated, but no nitrous air appears. The saturated menstruum has the appearance of water, unless iron be present : the black calx is very sparingly dissolved, yet a saturation is effected by means of a large quantity of the calx—phlogistic additaments complete the solution ; but these are not necessary if the acid be employed in a phlogisticated state. In this case the decomposition of heat seems to have less effect, as the menstruum, being more volatile than the vitriolic acid, is dissipated by a lower degree of heat. The green calx is acted upon in the same way as by the vitriolic acid : the solutions when pure deposit no solid crystals, although the evaporation be conducted with the most cautious slowness.

Reguline manganese is dissolved in the usual manner by the marine acid, as is also the white calx ; nay, the black is taken up in the cold by this menstruum, and communicates to it a red colour. I had before conjectured that the red calx is richer in phlogiston than the black, an opinion which is confirmed by a circumstance which occurs here. Marine acid contains phlogiston as one of its constituent principles ; and the black calx, by means of a superior attraction, seizes a part of this phlogiston, and acquires a certain degree of solubility : but this

this union is very slight, and may even be destroyed by the simple affusion of water: if, however, the red solution be exposed to a digesting heat for some hours, an intestine motion like an effervescence takes place; the smell of dephlogisticated acid is perceived, and the calcined manganese is taken up in such a manner as to be only separable by an alkali. The part of the acid which, by its phlogiston, has rendered the calx soluble, puts on the appearance of a red vapour, and flying off manifests itself by a peculiar odour: if sugar be employed, the decomposition of the menstruum is not necessary, nor is any smell of aqua regia perceived; other suitable phlogistic matters in the same way effect the solution of the black calx; nay, mercury itself, and even gold, neither of which yields directly to the marine acid, yet supply calcined manganese with their phlogiston; and, being thus dephlogisticated, are dissolved in the menstruum along with it.

Salited manganese scarcely yields distinct crystals, but only a saline mass, which attracts the moisture of the air: the precipitate by alkali is occasionally either white, yellow, or black.

As the fluor acid, united with manganese, forms a salt difficult of solution, it is thence sufficiently obvious, that the solvent power of that acid is extremely weak; for the particles, being surrounded by a saline crust, are freed

freed from the action of the menstruum, yet, upon repeated additions, the acid may be saturated. If fluorated volatile alkali be added to a solution of manganese made in another acid, instantly a double elective attraction takes place, and a fluorated manganese falls to the bottom.

The same is true of the phosphoric acid. The microcosmic salt, added to manganese dissolved in another acid, by a double affinity precipitates a phosphorated manganese.

The power of vinegar is weak, yet it dissolves the regulus in the way above described, and may even be saturated with the black calx, if that calx be added in large quantity. This combination yields no crystals; and after evaporation quickly deliquesces again.

Not only reguline manganese, but also the black calx, is taken up by the acid of sugar; but the saturated solution deposits a white powder scarcely soluble in water, unless it be sharpened by an acid. This salt grows black in the fire, but on addition of the saccharine acid, easily again acquires a milky colour. Manganese is precipitated in the form of crystalline atoms, by acid of sugar, from its solution in vitriolic, nitrous, or marine acid.

The acid of tartar, which is similar to this, takes up the black calx even in the cold, but the colour of the solution is a reddish brown; however this tinge is discharged

charged with effervescence in a digesting heat; a part of the menstruum is therefore decomposed, and yields its phlogiston to the calx, as has been already observed of the marine acid; besides, the tartarized vegetable alkali, added to any solution of manganese, immediately throws down tartarized manganese.

The circumstances already mentioned take place with the acid of lemons, which in this instance possesses altogether the same properties.

The weak aerial acid saturating water, attacks both the regulus and the black calx: the manganese, thus dissolved, if not mixed with iron, separates in the form of a floating white pellicle; by tincture of galls, or an alkali, it is precipitated white: if it is the regulus which has been employed, a peculiar smell, resembling that of burning fat, is perceived.

A very minute portion of the black calx, added to an alkali in fusion, immediately tinges it of an elegant blue, or sometimes a green colour, if iron be present; hence it is that pot-ashes are sometimes found variegated with blue or green: the green solution in a close vessel gradually deposits its iron, and then, the yellow being discharged, it becomes blue: exposed to the open air, the alkali attracts the aerial acid, and the black calx is deposited, a deposition which is more quickly effected by a few drops of
a stronger

a stronger acid, or even by a large quantity of water; by this last the solution grows first violet, then red, and at length all colour vanishes, the black particles which before had been red being deposited: these particles, while red, had been equally dispersed through the clear mass; but being more completely deprived of their phlogiston, at length grow black.

(H) Eight parts of calcined manganese, by a gentle heat in a glass retort, take up three of sulphur, and produce a yellowish green mass, which is acted upon by acids, dissolving the metal with effervescence and an hepatic odour: the sulphur which remains after the generation of the hepatic air may be collected on a filter.

Reguline manganese appears to reject sulphur.

(I) These properties evidently shew, that manganese differs considerably from all metals hitherto known; in fusibility and colour it somewhat resembles iron; in its strength of attraction, specific gravity, and in producing a colourless vitriol, it approaches to zinc; but in other properties is totally different.

Iron is malleable and magnetic when it retains the greatest possible quantity of phlogiston: during solution in acids it exhibits a green colour, but upon a greater dephlogistication it grows pale; and the last lixivium, which refuses to crystallize, puts on a reddish

a reddish brown appearance. The vitriol of this metal, dissolved in water, is decomposed spontaneously in an open vessel, and separates an ochre—this deposition is accelerated by heat: the calx deposited is of a reddish brown, or at least reducible to that colour by a due degree of heat.

Zinc is of a white colour, easily fusible, and inflammable by ignition in open vessels, and burns with a most elegant flame, sending forth white flowers; but in close vessels the metal, being volatile, rises by the force of the fire: it forms with copper a yellow compound, which, when the relative quantities are properly adjusted, resembles gold: it is easily dissolved in all the acids, whether it be reguline or calcined, and forms a colourless solution: it yields a white calx, which is not rendered black by a red heat of some minutes: and it never tinges glass red: these, and its other properties, readily distinguish it from manganese. The entire habit of the latter with phlogiston is so singular, that it cannot easily be confounded with the other metals; for what metallic calx, except the black calx of manganese, is able to decompose marine acid and volatile alkali, nay to separate the phlogiston even from gold itself?—What other, when deprived of its phlogiston, can form a blue solution with alkaline salts, and a red with acids, which it again loses by means of phlogistic additaments?—

What

What other is there which, by the difference in the quantity of phlogiston, can exhibit colours so various and so distinct, namely, white, red, green, and black? It is generally thought that black calxes contain the greatest quantity of phlogiston, but in this case the black contains least of it.

Besides, manganese, though tortured in many different ways, could not be changed into iron or zinc, or any other known metal, but obstinately retained its own properties; therefore, until experiments, free from the least ambiguity, shall have shewn that this is derived from other metals, it must be considered as a distinct metallic substance, unless we wish to overturn the certainty of natural philosophy altogether, by indulging fallacious conjectures. The difficulty with which the martial iniquament is separated, indicates no more than the existence of a very intimate union. The regulus eliquated from the black manganese of Sweden, exposed in an Hessian crucible for a quarter of an hour (without any additament) to a violent heat, lost 0,33, which had separated in the form of a brownish yellow scoria. The regulus was not yet magnetic; and, by the addition of sugar, the acids extracted pure calx of manganese; at least, with phlogisticated alkali, no traces of Prussian blue could be discovered. The remainder of the regulus weighed 67 lb.; and, upon repeating the operation,

operation, the part which was magnetic weighed only 25 lb. and the black scoria was found contaminated a little with iron. This regulus, fused again, yielded only 17 lb. and dissolved in acids, by the addition of phlogisticated alkali, both white and blue particles were deposited, the former of which appeared most numerous; so that we may conclude, that in 100 parts of manganese there are not present, of common iron, more than 0,08.

The method by which the quantity of iron may be accurately examined, will be described § VIII. B.

§ VIII. *Method by which Manganese, when mixed with Iron, may be distinguished and separated.*

The ores of iron and of manganese are very frequently loaded with both metals; and although the iron ores are often found without manganese, yet those of the latter are scarcely ever free from the former. The calxes of these two metals are also frequently found together in the vegetable kingdom.

(A) In order to discover the presence of manganese in iron quickly and easily, the blow-pipe may be employed in the manner above described (§ IV.); but no redness appears, if a particle of complete metal be added to the salt in fusion, as the tinge is

destroyed by the phlogiston of the iron (§ VI. F and G). The purpose is generally better answered by a small portion of the metal well calcined; but upon charcoal the metallic calx attracts phlogiston from the support, therefore the fusion must either be performed in a silver spoon, or else the red colour must be induced by a small piece of nitre. A person used to the process will easily know the presence of manganese, and even be able, from the phenomena, to judge of its quantity.

In a crucible too, the presence of manganese is discovered without difficulty. To a piece of iron, weighing a few assay pounds, and made red hot, let there be added about five times the quantity of crystallized nitre; and let the same quantity be again added when the effervescence has ceased: if any manganese be present, a green ring will be found round the middle of the inside of the crucible; if the quantity be considerable, it will not be necessary to add the nitre a second time;—the crucible must be removed from the fire while the mass is red hot.

(B) Let a determined weight of the iron suspected to contain manganese be dissolved in a large quantity of nitrous acid, let it then be evaporated to dryness, and at length made red hot: let the residuum be weighed, and put into diluted nitrous acid, together with a small piece of sugar; and if any manganese
2 be

be present, after a few hours the menstruum, when saturated with aerated alkali, will yield a white metallic calx, which may be thus totally abstracted: let the remainder, which is totally deprived of manganese, be elixated, dried to ignition, and finally again weighed—the difference of weight, before and after the extraction, will shew the quantity of calcined manganese; and this being given, the corresponding quantity of reguline manganese is easily determined, as that metal gains 0,33 by calcination. The solution itself also, precipitated by a fixed alkali, affords a white calx, the knowledge of which easily determines the quantity of the reguline manganese; for experiments shew that 100 parts of this metal dissolved, yield 180 of white calx.

The white calx thus obtained is seldom entirely free from iron, as it is very difficult to deprive that metal so far of its phlogiston, that the nitrous acid, especially when phlogisticated, cannot take up some portion of it: but if the white calx, obtained as above, be well calcined, and again dissolved in nitrous acid, by means of the addition of sugar, the iron remains for the most part undissolved; at the beginning too, the martial inquinament, being weaker in attractive power, may be precipitated by a few drops of volatile alkali.

Iron, contaminated with manganese, if powdered and plunged into a solution of

Q²

martial

martial vitriol, is gradually depurated; for, in virtue of its superior attraction, the acid separates from the iron, and dissolves the manganese.

§ IX. *Proximate Principles of the white Ores of Iron.*

These things being premised, we are enabled to judge properly of the composition of our ores, namely, they always consist of lime, iron, and manganese, but in proportions infinitely varied; for we shall pass over in silence the foreign matters, which we have already mentioned as being sometimes present (§ VI. B).

(A) The presence of lime is indicated by the effervescence, more or less remarkable, occasioned by the pulverized ore (§ VI. A); by its occasioning an heat in water, when sufficiently burned; by its separating a cream (§ V. A); and by the whitish opacity occasioned upon cooling, in the nitrous globules, when too much loaded with it (§ IV. B). Other circumstances tend also to prove the same thing; but the humid solution (§ VI. D) it is which puts the matter beyond doubt. If any portion of the metal should at the same time enter the menstrua employed (which is generally the case) that part ought first to be precipitated by phlogisticated alkali; and afterwards the lime, by an aerated alkali.

(B) Of

(B) Of the presence of iron there is no doubt; the crude ore is sometimes attracted by the magnet, which is almost always the case when it is burned; but sometimes, even after burning, this property is concealed by the smallness of the quantity, the iron frequently not exceeding 0,02, which nevertheless is discovered in the solution by means of phlogisticated alkali. The quantity of metal is discovered by reduction, either in the humid way or by fire, solution, and precipitation (§ v. E; VIII. B).

That iron, deprived of its metallic form, is present, easily appears, for the ore is seldom magnetic before roasting; nor on solution does it generate inflammable air, when the menstruum is vitriolic or nitrous acid: however, as the perfect ore yields without heat green solutions, except with the nitrous acid, and produces with the vitriolic acid a beautiful green salt, we may thence collect, that the deficiency of phlogiston is in this instance not greater than in martial vitriol.

(c) The presence of manganese is indicated by the most manifest signs, and that even in the state of white calx, unless when injured by lapse of time: these are, the blackness occasioned by calcination, either spontaneous or produced by fire (§ IV. A; VII. G); the habits, when examined by the blow-pipe (§ IV. VII. F) and by other experiments, both by fire (§ v. VII. A, F)

and by the humid way (§ VI. VIII. G). But what puts the matter entirely beyond doubt is, that the calx may be separated, and separately examined (§ VIII. B). White calcined manganese forms proportions of the whole mass very unequal. From the regulus of Eisenartz, 42 lb. in weight, 24 of white manganese is obtained (§ V. E); which weight also yields 13 lb. of regulus of manganese; the iron, therefore, is $42 - 13 = 29$: and in 100 parts of this ore, of calcined iron, as in green vitriol, about 38, of aerated manganese 24, and of aerated lime 38. The ore brought from the mountain, which in Sweden is called the western Silver Mountain, in the same way yielded 22 of calcined iron, of white calcined manganese 28, and of aerated lime 50.

§ X. *Use of the white Ores of Iron.*

It is well known to the skilful in those matters, how excellent the steel is which is produced by the white ores; although that the foundation of this excellence is an admixture of manganese has heretofore been unknown. In the reguli formerly eliquated (§ V. F.) the manganese formed about one third, by which, not only the hardness was increased, but a silver splendor communicated. The best proportions in mixing the metals must be determined by various and repeated experiments.

These

These ores frequently contain iron in such small quantity that they cannot properly be denominated from that metal; one or two hundredths are certainly of no such consequence: in such the calcareous earth abounds, which consequently by roasting is converted into quick-lime, but is black or brown, on account of the dephlogistication of the earthy base of the manganese. A black calx of this kind is got in the neighbourhood of Upland; this affords excellent mortar, which grows harder, and dries more quickly, than any other, even under water. This superior excellence is rather to be attributed to the manganese than to the iron, as the calcareous stones, deprived of manganese, though containing the same portion of iron as those of Lena, yet produce a mortar of a much inferior quality. We have calcareous stones in many places of Sweden, which grow black on burning, and which doubtless possess the same virtue.

We employ the black manganese in glass-houses for purifying glass: how this acts has been already explained (§ VII. F). It is very probable that calcareous earth, loaded with manganese, and deprived of iron, such as we have spoken of for building, may be applied to the same purpose.

DISSERTATION XX.

OF

N I C K E L.

§ 1. *Historical Introduction.*

TH E R E is found in the parts of Germany which abound in metals, an ore which is called *kupfer-nickel*, sometimes grey, but often of a reddish yellow colour, and polished. This name it probably first got and still retains from this circumstance, that although it has the appearance of containing copper, yet not the smallest particle of that metal can be extracted from it, even by fire. The first account we had of it was from V. Hierne, in a book published in 1694, written in the Swedish language, concerning the discovery of ores and other mineral substances.

Henckel.

Henckel considers it as a species of cobalt or arsenic, alloyed with copper, and Cramer refers it to the arsenical or cupreous ores; but neither they, nor any other person (as they themselves confess) were ever able to extract from it a single particle of copper. Several other philosophers acquiesced in this opinion, until that celebrated mineralogist Mr. Cronstedt first undertook an accurate examination of this mineral, and by many experiments, which were published in the years 1751 and 1754, shewed that it contained a new semimetal, to which he gave the name of *nickel*.

Almost all the Swedish mineralogists afterwards embraced this opinion, as also did many others, although the old opinion was not entirely deserted; for some were led rather by vague conjecture and specious appearance, than by satisfactory experiment; and Mr. Sage has lately attempted to establish the former theory by chemical reasonings and experiments. In the acts of the Royal Academy at Paris he described an analysis of nickel which he had undertaken, and upon this grounds an opinion that the new semimetal is composed of cobalt mixed with iron, arsenic, and copper.

In order to decide upon this subject many experiments are necessary, and these I undertook with a mind totally free from any preconceived opinion; and though upon this occasion the scarcity of the mineral prevented

vented me from entirely removing doubt, yet I trust that so much of the truth has been laid open, that when a sufficient quantity of this substance can be obtained, it will be found no difficult matter to establish the truth in the most decisive manner.

§ II. *Eluquation of the Regulus.*

In order to obtain the regulus of nickel, the ore must be first subjected to roasting, during which a quantity of sulphur and arsenic, greater or less according to the nature of the ore, is expelled; so that it sometimes loses upwards of half its weight, but frequently not above 0,3. This ore, though long and completely calcined, does not always acquire the same colour, but in general becomes greener in proportion as it is more rich; sometimes (especially if suffered to lie at rest) its upper surface is covered with green vegetations, somewhat of the form of coral, which are hard and sonorous.

Let a double or triple quantity of black flux be added to the roasted powder, and the mixture well fused in a forge, in an open crucible, covered with common salt, according to the usual method.

The vessel being broken, a metallic globe is found at the bottom, under the scoriae, which are brown or black, or sometimes even blue: the weight of the globe amounts

amounts to 0,1, 0,2, or at the most 0,5 of the crude ore.

This, however, is far from being pure; for although the roasting be ever so violent and long continued, yet a considerable quantity of sulphur, but especially arsenic, still remains concealed in the regulus, exclusive of cobalt, and a great proportion of iron, which last is generally so prevalent as to make the regulus magnetic; and this variety of heterogeneous matter is the cause why the regulus varies much, not only in respect to its fracture, the polished surface of which is either smooth or lamellated, but also in regard to its white colour, which is more or less yellow or red.

It is obvious from hence how necessary it is to depurate the regulus, if we wish to judge rightly of its genuine nature and properties: I have therefore undertaken a great variety of laborious processes for this purpose;—to describe them all circumstantially would far exceed the limits of this Essay; I shall therefore only mention the most remarkable, and that concisely; for in writing to metallurgists it is by no means necessary to describe all the minute circumstances attending an operation.

§ III. *The Regulus depurated by Calcination and Scorification.*

In order to discover the effect of repeated calcinations and scorifications, the following experiments

experiments were made with a certain regulus of nickel found in the Suabian collection of the Upsal Academy, which had been eliquated by Mr. Cronstedt, and whose specific gravity, taken by a very exact hydrostatic balance, was to that of distilled water as 7,4210 to 1,0000.

(A) Nine ounces reduced to powder were exposed in several dishes, for six hours, to an exceedingly vehement heat, under the dome of an assay furnace; by this the arsenic was first dissipated with a fœtid smell; a sulphureous odour was next perceived; afterwards a quantity of white smoke, without the garlic smell, which probably arose from the sublimation of the more dephlogisticated arsenic: when the heaps were hot they began to swell, and green vegetations sprang out from all the surface, resembling moss, or the filiform lichen; there remained at the bottom a powder of a ferruginous ash-colour. In this operation 0,13 were dissipated.

(B) Half an ounce of this calx, fused in a forge for four minutes, together with three times its weight of black flux, yielded a regulus the surface of which was reticulated, all the areolæ being hexangular, with exceeding slender striæ, diverging from a tuberculated center: it weighed 0,73 of half an ounce, was obedient to the magnet, and when scorified with borax left a blackish glass.

(c) This

(c) This regulus being again roasted, first yielded a garlic smell, and after a visible inodorous fume, together with vegetations as before.

(D) The roasted powder being reduced by the black flux, and taken out of the vessel, a smell of arsenic was again perceived: the fusion was repeated with the calx and borax, and nothing appeared but some obscure signs of cobalt.

(E) The regulus of nickel, roasted a third time, yielded but little smell of arsenic; no vegetations appeared; and finally the metallic calx had rather a ferruginous than a green colour.

(F) After reduction in the fourth calcination nearly the same phenomena appeared.

(G) Reduction being performed with lime and borax, the regulus, when first fused, lost much of its iron, which adhered to the black scoriæ; it soon acquired an hyacinthine colour without any remarkable mixture of cobalt; it was now but little obedient to the magnet, and its specific gravity 7,0828.

(H) The regulus was again roasted (the fifth time); but upon the gradual addition of powdered charcoal to the dishes when red hot, a prodigious quantity of arsenic, which was before imperceptible, flew off in the form of smoke; for it is the nature of this semimetal, that unless there be present a certain quantity of phlogiston, with which

it

it may unite, it does not yield to the action of fire, but remains fixed. The powder was treated in this way, until no more smoke or garlic smell appeared, although charcoal was again added.

(I) On reduction a regulus was obtained of a lamellated and tenacious texture, which yet, when the vessel was removed from the fire, diffused an arsenical odour.

(K) The roasting was therefore repeated a sixth time, and continued for ten hours, and by powdered charcoal arsenic was expelled, distinguishable not by the sight but by the smell; the colour of the metallic calx was obscurely ferruginous, mixed with a green scarcely visible.

(L) The reduction being effected with equal parts of the white flux, lime, and borax, a regulus was obtained, semiductile, highly magnetic, and soluble in nitrous acid, to which it communicates a deep green colour; yet there remains a blackish mass which eludes the force of the menstruum, which afterwards grows white, and, set upon a burning coal, flies off without any remarkable arsenical smell.

(M) The regulus was then six times fused with lime and borax; the scoria hence arising resembled the hyacinth in colour, but a green metallic calx surrounded the regulus, which, as before, was obedient to the magnet, and, being semiductile, broke tenaciously,

tenaciously, that is, the broken part was rendered rough by extended threads.

(N) After all these roastings the regulus was exposed during fourteen hours to a very strong heat; after this powdered charcoal was added by degrees, without any dissipation of arsenic, or loss of weight: the colour of the roasted powder was ferruginous, with a very weak tinge of green.

(O) After reduction, a very small globule, still magnetic, was found among the scoriæ, which were much loaded with iron. Of this globule we shall speak more at large in § IV. 1, &c.

§ IV. *Eluquation of the Regulus from the Ore of Los.*

The nickel ore which is got at the mines at Los, in Helsing, was examined and depurated in the following way:

(A) The roasting was performed in the usual way.

(B) As was also the reduction.

(C) The regulus was then calcined, and the powdered charcoal was added by degrees, until all the arsenical smoke had ceased, and the calx of nickel acquired a deep green colour.

(D) This being reduced, a magnetic regulus was obtained, which yet, when fused with lime and borax, was not obedient to the

the magnet, and yielded a scoria of a deep blue.

(E) Powder of charcoal was gradually added, during ten hours, to a regulus of this sort sufficiently calcined (if this be instantly done, the reguline particles readily coalesce) by which means a quantity of arsenic was dispersed, and a ferruginous powder, of a colour approaching to green, remained.

(F) After reduction with the black flux, lime, and borax, the scoriæ were tinged partly with iron, and partly too with the nickel;—the white regulus was strongly attracted by the magnet.

(G) But afterwards, though phlogiston was added abundantly to the mass in the dishes, for the space of fourteen hours, yet neither smoke nor smell betrayed any sensible dissipation of arsenic, nor was the weight diminished; but, on the contrary, it was increased $\frac{1}{5}$ by the roasting;—the metallic ferruginous calx was scarcely green.

(H) After the reduction the regulus was semiductile and magnetic.

(I) This, first fused with lime and borax, and afterwards united with that which was mentioned in the preceding (§ III. o) yielded a white semiductile regulus distinct, with the colour of green calx, and hyacinthine scoriæ.

(K) The same regulus was fused with sulphur, and one-half its weight of the mineralized

neralized mass, imperfectly roasted, was united by fusion with a portion of the crude mineral; this sulphurated nickel, well calcined, and reduced with a double quantity of black flux, yielded a regulus obedient to the magnet, which was nearly as refractory in the fire as forged iron.

As sulphur has a strong attraction for nickel, I had hopes that this mineralizing substance, not being sufficient to saturate both the nickel and the iron, would desert the latter, and adhere to the former; by which means, the iron entering the scoriæ might be easily separated. The following paragraph will shew the effect of this conjecture.

§ v. *Nickel depurated by Sulphuration.*

(A) 800 parts of the regulus of Cronstedt (§ III.) fused with sulphur and a small quantity of borax, yielded a mineralized mass of a reddish yellow, amounting to 1700.

(B) One-half of this, when first exposed to fire in a roasting dish, began to grow black, then the heat was increased until vegetations arose; the metallic calx now remaining weighed 652.

(C) This half, fused with borax, and the other part not burned, yielded a sulphurated regulus of a whitish yellow colour, in weight 1102.

(D) The same regulus, by a calcination

which lasted for four hours, was first covered with vegetations, and afterwards, upon the addition of powdered charcoal, diffused a continued odour of arsenic; the weight of metallic calx, which was of a dilute green, was 1038.

(E) After reduction, a whitish yellow regulus was found, in weight equal to 594, semiductile, highly magnetic, and, at the same time, exceeding refractory.

(F) This was again fused with sulphur, which being done, the weight was equal to 816; one-half of which, roasted to greenness, united by means of fire with the other, still sulphurated, and in weight 509, scarcely obeyed the magnet. After a calcination of four hours, during which, by means of the phlogiston, much arsenic flew off, the powder put on an ash-colour, a little greenish, in weight 569, which by reduction yielded a regulus the surface of which was red, and which, upon breaking, appeared of a white ash-colour, very friable, equal to 452; the specific gravity of which was 7,1730.

(G) The regulus, mineralized a third time with sulphur, was treated in the same way as before with powder of charcoal, so long as any vestiges of arsenic remained, which required a vehement calcination for twelve hours. The powder then remaining was of an ash-green colour, and weighed 364; but the regulus obtained by means of a reduction, effected by exposure to a most violent

violent heat in a forge for three-quarters of an hour, was so refractory that it only adhered imperfectly to the scoriæ, which were of a distinct hyacinthine colour; nor could it be reduced to a globule by the addition of borax, though urged by the same vehemence of fire. The absolute gravity of this regulus was 180, but its specific gravity 8,6666; and it not only adhered strongly to the magnet, but to any other piece of iron, nay the small pieces of it attracted one another; it was besides so ductile, that from a globule, whose diameter did not exceed one line, a plate of three lines in diameter and upwards might be obtained by the hammer: it was of a whitish colour, mixed with a glittering kind of red: dissolved in volatile alkali, it yielded a blue colour, and in nitrous acid a full green.

One hundred parts of the same regulus, beaten out into thin plates, after a calcination of four hours, were covered with a crust in appearance martial, under which was a green powder, and within a nucleus, consisting of reguline particles unchanged: the weight was increased by 5. The friable matter, reduced to powder, put on a brownish green colour, and after a calcination of four hours more, concreted at the bottom in the form of a friable blackish crust, which was strongly magnetic, and weighed 100; the crust was afterwards comminuted, and roasted for three hours,

R 2

with

with the addition of powdered charcoal, yet neither were any vestiges of arsenic discovered, nor was the magnetic power destroyed; but the weight was now 105, and the colour little changed. This powder, fused for an hour with lime and borax, yielded a regulus of 72 lb.; this was red, angular, semiductile, and altogether magnetic, the specific gravity of it was 8,8750. The same globule, dissolved in aqua regia, was indeed precipitated by martial vitriol, as if loaded with gold; but the sediment was very easily soluble in nitrous acid, hence it appears not to be gold. But most of the reguli which we obtained, shewed no signs of precipitation with martial vitriol; hence it clearly appears, that even if gold be sometimes present, yet it is not always the case.

(H) 800 parts of the ore of nickel, which is found in Saxony at Johan-Georgenstadt, roasted for fourteen hours, and freed as much as possible from arsenic, by means of powdered charcoal, lost 248 of their weight. After reduction, and the first mineralization performed in the usual way, it was remarkable, that the latter sulphurated regulus, which before calcination weighed 230, afterwards was equal to 242; and after another sulphuration of the same kind in the last calcination, had its weight increased from 70 to 78: the regulus last obtained was equal to 22, obedient to the magnet, possessing

possessing a specific gravity of 7.3333, and yielding with borax an hyacinthine glass : it was with difficulty calcined, but at length fell into a greenish powder, and with nitrous acid yielded a solution of the same colour.

(I) The process of mineralization and calcination described in (H), was repeated with 100 parts of the ore of Los, and that without any increase of weight : the regulus finally obtained was in absolute gravity 1, in specific gravity about 8 ; it tinged borax of an hyacinthine yellow, and nitrous acid of a green colour.

§ VI. *Nickel depurated by Hepar Sulphuris.*

As it appears from experiment, that cobalt is more easily dissolved than nickel, by hepar sulphuris, and that these substances may thus to a certain degree be separated in the fire ; a suspicion arose, that unequal degrees of affinity might produce the same effect with iron and nickel.

(A) 58 parts therefore of regulus of nickel, which had before been sulphurated (§ v. G), fused with 1800 of saline hepar sulphuris, then dissolved in warm water, filtered through paper, and precipitated by an acid, yielded a powder, which, roasted in a dish till the sulphur was consumed, was found of an ash-colour, and weighed 35.

R 3

(B) The

(B) The residuum, which could not be dissolved in warm water, being freed from sulphur by means of fire, was also of an ash-colour, and weighed 334.

(C) This residuum, reduced by the black flux, yielded a friable regulus, which was indeed but little magnetic, yet, when fused again with borax, exerted that property (which had before been weakened by the sulphur) in a higher degree.

(D) The same experiment was tried with a calcareous hepar, according to the direction of Mr. Beaumé—viz. calx of nickel, gypsum, colophony, and white flux, were taken in equal proportions; these, mixed and fused, yielded a powdery, squamous, reguline mass, which, when fused with borax, produced a regulus possessing the properties of nickel (but not entirely destitute of cobalt), which obeyed the magnet, and even after two solutions in nitrous acid, and various reductions by fusion with borax, did not part with its iron; it also retained the sulphur obstinately.

(E) Regulus of nickel was dissolved, in the *via sicca*, by a saline hepar sulphuris, and upon the addition of a quantity of nitre, sufficient only to destroy a small part of the hepar, the regulus which had been suspended by it was separated and fell to the bottom. This regulus of nickel, upon examination, appeared more pure, and generally, at least for the most part, deprived of

of cobalt, but still containing iron. In like manner nickel is always very distinctly precipitated by regulus of cobalt, as this latter is attracted more powerfully by the hepar sulphuris.

Nickel dissolved by saline hepar sulphuris in fusion, may be precipitated by the addition of iron, copper, tin, or lead, and even by cobalt: the regulus obtained is scarcely ever attracted by the magnet; but whoever concludes from thence that no iron is present, will be deceived; for this metal (the regulus of nickel), when properly freed from the heterogeneous matters which impede its action, acknowledges the magnet's power very plainly.

§ VII. *Nickel depurated by Nitre.*

Finally, Nitre, which attracts phlogiston more powerfully than any other substance hitherto known, was employed; it was hoped that this would more easily scorify the heterogeneous matters, because nickel seems both to lose its phlogiston more slowly, and to recover it more quickly, than those matters.

(A) One part of Cronstedt's regulus was added to twelve of nitre, ignited in a crucible, and kept in an equable degree of heat for the space of an hour; at first some weak flashes appeared, probably from the residuum of the sulphur; afterwards a large

R 4

quantity

quantity of arsenic was thrown out; finally, the sides were covered with a blue crust, occasioned by the cobalt, and a green matter remained at the bottom. This fused again for an hour, with twelve parts of nitre, tinged the internal sides of the vessel of a green colour; and finally a brownish green mass, much less in quantity than in the former operation, was found collected at the bottom.

The green matter, treated in the same way a third time, for two hours, left a grey scoria at the bottom, which, with black flux, yielded no regulus.

Another portion of the same regulus, fused with nitre in the same way, was dissolved and became green; yet, being freed from the alkaline salt by means of water, neither did this yield any regulus with black flux, but scoriæ of an hyacinthine colour, mixed with blue; which tinged nitrous acid of a green colour, concreted into a jelly, and upon evaporation left behind a greenish calx.

(B) Another portion of Cronstedt's regulus was kept some hours in the crucible, with sixteen parts of nitre; by this means, at first all the arsenic was separated, then the phlogisticated nitrous acid flew off, and finally blueish green flowers penetrated the sides of the vessel. The mass being freed from alkali by water, and dried, was of a dilute

dilute green, and tinged borax of a greenish brown.

This was again treated in the same way with 12 parts of nitre; and after edulcoration yielded a powder still green, which, reduced with $\frac{1}{2}$ black flux, $\frac{1}{4}$ lime, and $\frac{1}{4}$ borax, in half an hour yielded a yellowish white regulus, both magnetic and malleable, and possessing all the properties of nickel; its specific gravity was 9,000. The inflammable ingredient was used in small quantity, that if possible the iron might enter the scoriæ.

(c) One part of the ore of los was strongly ignited in a crucible, for the space of an hour, with eight parts of nitre, and a detonation more distinct than with the regulus took place at first. The metallic calx, which was separated from the saline matter by water, was of a brown ferruginous colour, similar to that which is wont to remain after calcination with charcoal-dust. This by reduction yielded an ashen-white regulus, tenacious and magnetic, of the specific gravity 8,5573: the scoriæ were black. The regulus reduced to powder, and fused with 12 parts of nitre, lost much cobalt; and yielded a green calx, which, on reduction with double its weight of black flux, and $\frac{1}{2}$ quick-lime and borax, left nothing but distinct globules of nickel, tenacious and magnetic.

(d) One

(D) One part of Cronstedt's regulus was fused for three hours with 8 parts of nitre, in a crucible, to the cover of which an open glass tube was so adapted that the ascending vapour might be collected there: the operation being finished, white arsenic was found in the upper part of the tube; but in the lower a powder of a brown ash-colour, a little green, which tinged borax of an hyacinthine colour, and yielded a regulus so loaded with arsenic as not to be magnetic. The sides of the crucible were blue; but the saline green mass at the bottom on elixation deposited a green calx, which was kept ignited with 12 parts of nitre for the space of an hour, and became partly blue, partly green: but afterwards, when only $\frac{1}{2}$ of the green residuum was treated in the same way, the whole appeared blue: yet the green residuum was dissolved in nitrous acid, and rendered borax of an hyacinthine colour; so that it consisted of nickel surrounded by a blue crust.

(E) As the experiments above related shew, by means of nitre, the smallest traces of cobalt, which otherwise would be completely latent, I examined the various niccoline products in dishes, with the addition of nitre, under the dome of an assay furnace: namely, 1st. The regulus (§ IV. 1.) which was a little blue. 2d. The regulus previously dissolved in volatile alkali (§ X. A.) which manifested a considerable quantity

quantity of cobalt that had lain hid before. 3d. The regulus previously sulphurated, which assumed a bluish pellicle. 4th. The globules (c), which sent forth a copious quantity of blue flowers. 5th. The sublimate of the preceding article (d), which shewed exceeding weak signs of a blue: and finally, 6th. The hyacinthine scoræ of nickel, which were of a beautiful blue, yet contained so little cobalt that all the colour could be discharged from the glass of borax tinged by it, by means of the blow-pipe; which yet, on the addition of a small quantity of nitre, becomes blue: for the nature of metallic calxes is such, that they tinge glass the more deeply as they are more spoiled of phlogiston; and, on the contrary, when they recover their principle of inflammability to a certain degree, all tinge vanishes. The former of these effects may be produced by nitre, the second by fusion on charcoal, provided the calx be so small in quantity, and so greedy of phlogiston as to be saturated by it from the coal; otherwise these hyacinthine scoræ tinge acids of a green colour, and are precipitated like nickel by phlogisticated alkali.

§ VIII. *Nickel depurated by Sal Ammoniac.*

As iron is easily sublimed by means of sal ammoniac, it was tried, in the following manner,

manner, whether nickel could by this method be freed from iron.

(A) A calx of nickel, so much freed from cobalt as not to tinge borax with the slightest blue, was mixed with double its weight of sal ammoniac, put into a cucurbit covered with an head, and exposed to a fire gradually increased until the glass grew red: the bottom was stained with a very deep hyacinthine colour, and exhaled flowers, which adhered to the sides; these were partly ash-coloured, and partly white; which last did not rise so high as the former.

The residuum exhibited two strata, the upper of which was yellow, squamous, and shining, like aurum mosaicum: it yielded with borax an hyacinthine glass, but no regulus; after a few days it liquefied in the air, acquiring the consistence of butter, and a green colour. This residuum, with warm water, shewed the same properties and colour as calx of nickel; and the solution, which was green, became blue with volatile alkali, but with tincture of galls shewed no vestiges of iron; a circumstance which also took place in the flowers.

The inferior stratum contained a calx of nickel not yet converted into vegetations, and somewhat contaminated with marine acid: the colour was blackish, and, at the bottom, of a ferruginous brown. With borax it yielded an hyacinthine glass, and a friable

friable regulus of a reddish white, and scarcely magnetic.

(B) A part of the inferior stratum (A), sublimed with double its quantity of sal ammoniac, with the same degree of heat as before (which precise degree was employed in the following) yielded an hemisphere of an hyacinthine colour, and flowers of a very fine white; but the residuum was of a ferruginous brown, greenish on the upper part towards the sides of the vessel.

(c) To a portion of the inferior stratum reduced, was added 20 parts of sal ammoniac, which were sublimed in a retort; a blackish powder remained, which, as well as the bottom of the vessel, by calcination put on a green, and by scorification an hyacinthine colour.

(D) To the powder remaining (c) was added a double quantity of sal ammoniac, which was again sublimed extremely white, and the greenish mass which remained was of a ferruginous brown at the lower part.

(E) Sublimation was performed with the residuum of (D) and a double quantity of sal ammoniac, and yielded as before exceeding white ammoniacal flowers; and the residuum, which was very green, was altogether like a calx of nickel dissolved with the same colour in nitrous acid, and by reduction yielded a regulus of nickel, white, brittle, and very little magnetic.

In

In each sublimation the volatile alkali rose first, then sal ammoniac, and finally a portion of marine acid came over into the receiver.

§ IX. *Nickel depurated in the humid Way by nitrous Acid.*

After so many experiments made by the *via sicca*, many others were tried in the way of solution, beginning with the crystallized salt, (which, being composed of nitrous acid and nickel, shall be called nitrated nickel) by which, if possible, the iron being dephlogisticated, would separate from its menstruum.

(A) Nitrated nickel, sprinkled during calcination with charcoal-dust, sent forth a large quantity of arsenic, and after reduction yielded a regulus, grey, semi-ductile, and magnetic.

(B) This being again dissolved in nitrous acid, precipitated by fixed alkali, and reduced, yielded a brittle regulus.

(C) The same being a third time dissolved, yielded a regulus semi-ductile and magnetic.

(D) This operation was repeated a fourth time.

(E) The regulus, when dissolved a fifth time, was so much diminished, that the white calx obtained by precipitation could not be any farther examined.

In

In all these solutions a blackish residuum presented itself, which, when suffered to remain in the acid, grew white by degrees; but whenedulcorated, and laid on a burning coal, exhaled a sulphureous smoke, and left a black powder soluble in nitrous acid.

§ x. *Nickel depurated by Means of volatile Alkali.*

In order to discover the effect of caustic volatile alkali, in depurating nickel, a portion of the regulus of Cronstedt, dissolved in nitrous acid, precipitated by fixed alkali,edulcorated, and dried, was treated in the following manner:

(A) 487 parts of this calx, immersed in a superabundance of volatile alkali, after twenty-four hours yielded a residuum = 50, of a blackish green, and a solution of a blue colour, which, when filtered and inspissated to dryness, yielded a powder of a light blue colour = 282: this, reduced with black flux, produced a regulus, white, semi-ductile, and highly magnetic, = 35, and whose specific gravity was 7,0000: the scoria which remained was a light red, but, mixed with borax, put on an hyacinthine colour, which yielded a regulus = 30. This regulus, united with the former by means of fire, was very refractory, so that even with the addition of borax it could not be fused by the blow-pipe: during calcination,

cination, with an abundant addition of charcoal-dust, it did not send forth a smell either arsenical or sulphureous: in a following reduction it yielded an hyacinthine scoria, and the remaining flocculi, dissolved in nitrous acid, formed a very green solution, which, upon addition of volatile alkali, let fall a powder of the same colour.

(B) From 50 parts of the blackish green residuum was obtained a regulus of a clear white colour, brittle, squamous, but little magnetic, = 13, and of a specific gravity = 9,3333. A scoria of an obscurely blue colour, the upper part of it hyacinthine, was found at the bottom of the vessel. The regulus was easily fused, and tinged borax first of a blue, then of an hyacinthine colour, upon which it grew more strongly magnetic: by the assistance of heat it dissolved in nitrous acid, and was of a beautiful blue. During this solution a black powder appeared, which first floated like flocculi, but became white, and fell to the bottom; and afteredulcoration, being exposed to the fire, was for the most part dissipated with a sulphureous smell; but there still remained at the bottom a little mass of a brown colour, soluble in volatile alkali: this solution was precipitated by phlogisticated alkali, and a powder thrown down of the colour of calx of nickel; this soon grew blue with volatile alkali.

Hence,

Hence, therefore, it appears, that nickel is easily and totally dissolved in the volatile alkali, unless the efficacy of the menstruum be obstructed by the presence of sulphur.

§ XI. *Nickel can scarcely be obtained in a State of perfect Purity.*

Upon considering all the experiments above related, it easily appears, that it is scarcely possible to obtain a perfect and compleat purification of nickel from all heterogeneous mixture, by any means, at least, hitherto known. The sulphur is with difficulty expelled by calcinations and solutions (§ III. L; IX. and X.); arsenic adheres still more strongly (§ III. and IV.); but by means of charcoal-dust and nitre is entirely expelled (§ III. N; VII. B); cobalt adheres the most pertinaciously of all, for by the addition of nitre its presence has been detected even in products where it could not by any other method. No doubt its quantity had been so much diminished by the nitre, that in solution it was totally imperceptible (§ VII. D), would scarcely tinge borax, and the tinge which is communicated is discharged with the blow-pipe, by the phlogiston of the charcoal; all which circumstances (as the colour of cobalt is very rich) demonstrate its being present in exceedingly small quantity (§ VII. E): but I am the rather inclined to think, that even

this small portion may be separated; because it is certain that the last productions of the blue colour are not to be ascribed to cobalt but to manganese, as we shall demonstrate more clearly hereafter (§ XII.); yet in practice the separation is extremely troublesome; for these reliquia, extracted by the nitre, envelop the nickel itself (which in this operation becomes very spongy) and adhere so closely to it, that mechanically they cannot possibly be separated, and scarcely by menstrua, as both the substances are thereby dissolved: by fire too they enter the scorïa; at least in these two methods so little difference is discernible, that unless a large quantity together be subjected to the operation, all the nickel vanishes together with the cobalt.

In the present case then the iron alone remains, and the quantity of this cannot be diminished beyond certain limits; the magnet readily discovers its presence, and not only the reguli, tried in different ways, readily adhere to it, but some of them actually acquire a magnetic power (§ V. G), a circumstance highly worthy of observation: but the tenacity and difficulty of fusion, which increase the more as the operations are longer continued upon the nickel, plainly shew that no hope remains of separating the iron; so that neither the scorifications, nor the sal ammoniac (§ VIII.), nor the nitre, nor the nitrous acid (§ IX.), nor, finally, the volatile alkali

alkali (§ x.), have effected this purpose; although Juncker says, that nitre attacks iron so powerfully that from a pound of steel filings, detonated with an equal quantity of nitre, then fused and elixated, no more than half an ounce of crocus is obtained.

Besides these heterogeneous matters, bismuth is also sometimes present; but this is very easily separated; for if the solutions made in acids be sufficiently diluted with water, the menstruum is so much weakened, and the calx of bismuth falls to the bottom like a white powder.

§ XII. *Whether Nickel be a distinct Metal.*

It may now be properly enquired, whether nickel be a distinct metal, or whether it be a mixture made by the hands of nature, from others intimately united?—We have already observed that arsenic, copper, cobalt, and iron, have been by various authors considered as its proximate principles.

With respect to arsenic, we may very safely exclude it from the number, as the experiments above described shew that it may be entirely expelled.

It cannot be doubted but that copper is present in some ores of nickel, and therefore may easily be mixed with the regulus; but the greater number are entirely without it. It is true that nickel is totally soluble in volatile alkali, and that this so-

lution is of a blue colour (§ x. B); but if this argument held, there would be nothing found here but copper; and if this were the case very different phænomena would appear from those which the nickel produces. That both these substances form with volatile alkali solutions of the same colour, no more proves the identity of these substances, than does the yellowness of the solution both of gold and iron in aqua regia, prove the identity of those metals. Nickel and copper agree also in this property, that they are both precipitated from acids, and from volatile alkali, by iron; but in the manner of this precipitation a considerable difference appears. Let a piece of polished iron be plunged into a solution of nickel, and a yellow pellicle of nickel will by degrees adhere to it; which disappears upon touching, and soon grows black, unless the acid be well saturated or sufficiently diluted with water. A similar precipitation is observed if zinc be used instead of iron; but in solution of copper so much diluted that the precipitation on iron may be nearly similar to that of nickel, zinc is immediately covered with a crust of the colour of mountain brass.

The experiments above described sufficiently shew that cobalt does not belong to the essence of nickel (§ x. XIII. K); yet to these we shall add the following:—Nickel, dissolved in hepar sulphuris, is precipitated by

by cobalt; with what justice then can we affirm them to be one and the same? In the same way, nickel tinging borax or microcosmic salt, in the *via sicca* is thrown down by the addition of a proper quantity of copper; but this is not the case with cobalt. These circumstances are so remarkable as of themselves to banish all doubt. But with the acids a remarkable difference constantly occurs—1st, Cobalt tinges all these menstrua of a red colour, and yields crystals either of a yellow or bluish red; but nickel produces solutions and concretions of a fine green; it sometimes happens indeed that the red solutions yield greenish crystals; but this is to be attributed to nickel mixed in small proportion with the cobalt. 2d, Cobalt, united with marine acid, affords a sympathetic ink; but depurated nickel does not. 3d, Cobalt, dissolved in volatile alkali, is red; but nickel, dissolved in the same alkali, is blue. 4th, Cobalt does not, like nickel, separate, upon the addition of arsenical acid, a powder difficultly soluble. Many other points of difference there are, which may be passed over in silence.

Iron therefore only remains; and indeed there are many and weighty reasons which induce us to think that nickel, cobalt, and manganese, are perhaps to be considered in no other light than modifications of iron.

And first—in general we observe, that unequal portions of phlogiston, united to the

same iron, change its qualities in a remarkable manner: for instance, how very much do the different kinds of iron and steel differ? It is then to be observed, that nickel, cobalt, and manganese, whatever operations they may be subjected to, are so far from being deprived of iron, that on the contrary they thereby become more ductile, magnetic, and refractory. Again, the various colours which nickel, cobalt, and manganese exhibit, both by solution and by fire, are also exhibited by iron. Cobalt and manganese occasion a red colour in acids, and the latter in glass; nickel and manganese occasion an hyacinthine colour when fused with borax; a green is produced in acids by nickel, as also by its calx, and by manganese (M), when long and strongly calcined; and it often leaves behind a scoria of the same colour, if the reduction be performed with a saline flux. Finally, cobalt occasions a blue or rather a violet colour in glass; and the same is true of manganese dissolved in fixed, and nickel in volatile alkali.

Iron too exhibits all these varieties; for the acids take up this metal of a green colour, so long as it contains a certain quantity of phlogiston; but, in proportion to the diminution of this principle, a yellow, a red, or a brownish red colour is produced. It tinges glass, in the same manner, green, yellow, black, or red. If exposed to the fire for many hours together, with nitre, the bot-

tom and sides of the crucible, it is true, transude saline flowers, either blue, greenish blue, or greenish purple; but an efflorescence of the same kind is occasioned by nitre alone; for this salt, by a long-continued fire, penetrates the vessels, and immediately upon contact of ignited phlogiston is decomposed, and the alkaline efflorescences are made blue by the manganese, which is always present in the circumjacent ashes; these verge more to a green in proportion as the crocus martis is more copious; besides, iron itself is often found mixed with manganese.

From hence, therefore, it appears, that the blue flowers, which were expelled from nickel by means of nitre, are the produce of manganese, as these impart to glass nothing of the cobalt colour; besides, in the mineral kingdom we find the nephritic, smegmatic, serpentine stones, and jaspers, clays called from their colour *terres verdes*, and other green stones, *lapis lazuli*, native Prussian blues and other blue stones, together with many diversities of yellow and red, all deriving their colour from iron.

Whoever rightly considers these circumstances will think it not an improbable conjecture, that these semi-metals are derived from iron, of which they cannot be entirely deprived; and from hence will take occasion to examine this opinion by new experiments and observations, which may either

serve to establish or overturn it. In the mean time we should be carefully on our guard against such glimmering lights, which are generally fallacious. So long as no one is able to produce any of these metallic bodies from pure iron, and to explain, in a clear and intelligible way, the process by which manganese, cobalt, or nickel, may at pleasure be generated, such vague suspicions must give way to phenomena and properties which are constant, and the substances themselves continue to be considered of an origin altogether distinct and peculiar to themselves. It is sufficient for our purposes, that these metals possess distinct properties, and always preserve their own peculiar nature, until we shall be better instructed by faithful analysis and synthesis. There is no doubt that many metals, which have been a long time known and acknowledged to be distinct substances, would scarcely have endured more severe trials than nickel does. By the same rule, therefore, such metals may be alledged to be compounded. If the genesis of natural productions was to be established by fancied metamorphosis, the whole truth and certainty of natural philosophy must soon be overturned. So long as plausible conjectures are substituted for opinions formed on the sure base of experiment, we shall always embrace the shadow for the substance.

§ XIII. *Synthetical Experiments.*

Although the synthetical experiments which I undertook with intent to discover the origin of nickel, were in that view ineffectual, yet I think it proper to relate the principal of them, that the way may be more easy to others. The specific gravity of the copper, iron, cobalt, and white arsenic, employed, were 9,3243, 8,3678, 8,1500, and 4,0000, respectively.

(A) Equal parts of copper and iron, united by fusion with black flux, yielded a red mass, whose specific gravity was 8,5441, which tinged nitrous acid first blue, then green, afterwards yellow, and at length an opake brown.

(B) Two parts copper, and one of iron, united, had a specific gravity equal to 8,4634. The mixture yielded first a blue, then a green solution.

(C) Equal parts of copper, iron, and cobalt, yielded a regulus of the specific gravity 8,0300, which imparts to the menstruum a brown colour.

(D) One part of copper, one of iron, and two of arsenic, formed a brittle mixture of a specific gravity equal to 8,0468, which formed a blue solution.

(E) One part of copper, one of iron, two of cobalt, and two of white arsenic, yielded a brittle composition of a specific gravity equal

equal to 8,4186, which gave a brownish red solution, and in part precipitated spontaneously.

(F) One part of copper, one of iron, four of cobalt, and two of white arsenic, united by fusion, formed a mass of specific gravity equal to 8,5714 : the regulus, dissolved in nitrous acid, was as in (E), but more red.

(G) One part of copper, one of iron, four of cobalt, and two of white arsenic, acquired a specific gravity equal to 8,2941 ; they were dissolved with a red colour, and deposited a sediment.

(H) One part of iron, and four of white arsenic, fused, were dissolved with a yellow colour ; and, on the addition of phlogisticated alkali, immediately yielded a Prussian blue.

All these mixtures, exposed to the fire, left a calx, not green, like that of nickel, but brown, black, or ferruginous.

(I) One part of copper, eight of iron, sixteen of white arsenic, and four of sulphur, united by fire, on the addition of black flux, yielded a mass, which, though frequently calcined and reduced, yielded nothing but a ferruginous or brown calx : with nitrous acid it acquired a greenness, but on the addition of phlogisticated alkali, deposited a Prussian blue.

(K) Many experiments were also tried in the way of solution ; one of which it will be sufficient to mention.

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One part of iron was dissolved in six of nitrous acid, and also separated by one part of copper, and one of the calcined ore of cobalt, in the same quantity of the same acid; then the whole of the solution of iron was mixed with five parts of the solution of copper, whence a green and saturated nickel colour was formed, which, however, upon the addition of three parts of the solution of cobalt, was evidently obscured: the alkaline lixivium was dropped into this, by which at first a ferruginous brown sediment fell, the solution still remaining green; but afterwards all the blue was precipitated, by which at first all colour was destroyed; but afterwards a red appeared, occasioned by the cobalt dissolved in the alkaline salt. The sediment, when reduced, yielded a regulus similar to copper, and ductile, which tinged both glass and nitrous acid of a blue colour.

If a saturated solution of nickel be mixed with half its quantity of solution of cobalt, the green colour is much obscured; but four parts of the former, upon the addition of three of the latter, put off all appearances of nickel.

§ XIV. *Properties of depurated Nickel.*

I have not been able to determine accurately what are the properties of nickel when perfectly pure, as the perpetual presence of
iron

iron in some respect obscures its properties.

(A) The specific gravity cannot be ascertained, especially as the quantity of iron is unknown. Let us suppose that the purest nickel we can obtain, contains of iron a weight = p , and of real nickel = q ; as also that the specific gravity of the former ingredient is f , of the latter n , and of the mixture a ; then, from the known laws of hydrostatics $\frac{a q f}{p f + q f - a p}$. Now it appears by experiment, that the weight of iron is more increased by calcination than that of any other metal, even to 0,36: since then the calx of purified nickel increases $\frac{1}{5}$ (§ IV. G), if one half be ascribed to the nickel, as much must necessarily belong to the iron: besides, let $\frac{1}{2}$ the increment be subtracted, as owing to the charcoal-dust, nevertheless the residuum shews that more than $\frac{1}{4}$ consists of iron. Let therefore $p = 1$, $f = 8,000$, $a = 9,000$ (§ VII. B), q will be = 2, and $n = 9,600$. The data of this calculation were so taken, that the value of n should come out less than the truth; for the increment of the nickel is put equal to that of the iron, which is hardly probable; then the quantity of iron is estimated only at $\frac{1}{4}$, although it is certainly greater; and finally, $\frac{1}{4}$ of the increment is ascribed to the charcoal-dust, although other experiments shew that it adds little or nothing to the weight; hence therefore we conclude, that the true specific

specific gravity of nickel is not less than 9,000 at least. The calculation indeed supposes that the bulk remains unchanged in the mixture, which is a thing that rarely happens; but the error thence arising never exceeds 0,7, so far as is yet known, and perhaps, in the present case, is rather to be added than subtracted.

If a small portion of gold entered the composition, the greatness of the weight might thence be explained; but although this metal is almost always absent, as we have before observed (§ v. G), yet thirty-six parts of it, forty-eight of iron, and one of copper, were formed by fusion into a globule, the specific gravity of which was 8,8571, but was little soluble in nitrous acid; yet, after lying two hours in the menstruum, the gold was to be seen plainly, and with volatile alkali, the menstruum yielded nothing but a ferruginous brown precipitate, which in the fire put on the appearance of roasted iron; in all which particulars it differs from nickel.

(B) The solutions of nickel in all the acids are of a green colour. The vitriolic acid takes up the calx, and forms a green decaedral salt, of an aluminous compressed figure, the two opposite apices truncated; this acid scarcely attacked the regulus but by evaporation to dryness. The nitrous acid, by the assistance of heat, dissolves both the calx and the regulus, and forms blueish-green

green crystals, spathose and deliquescent. The marine acid dissolves both the regulus and the calx, but slowly, and not without the assistance of heat. Both nitrated and salited nickel, when fresh, deliquesce; but by long continuance in a free and warm air, gradually lose their acid, so that at length a green calx of nickel, mixed with iron and arsenic, remains behind. Acid of arsenic, with the calx of nickel, concretes into a green saline mass; but with the regulus it separates a saline powder difficult of solution. The fluor acid forms with calx of nickel (which it does not easily dissolve) crystals of a dilute green. The acid of borax scarce dissolves nickel directly, but takes it up by means of a double elective attraction. Vinegar forms with the calx spathose crystals of an intensely green colour: it is scarcely dissolved by acid of tartar, at least this menstruum is not tinged by it. Acid of sugar changes both the regulus and the calx to a white powder, not easily soluble in water. The acid of phosphorus has but little attraction for the calx of nickel, with which it does not form crystals, nay the solution is scarcely green. The acid of ants, by decoction or long digestion, attacks the newly-precipitated calx; for the solution is green, and upon evaporation yields crystals of a deep green colour; these are hemispherical, formed of filaments diverging from a center, and pellucid; they reject

reject spirit of wine, and are scarcely soluble in water, unless it be sharpened by an acid. Lemon-juice does not seem to act at all upon nickel.

All the acids are tinged of a very deep colour, and this property of nickel is extremely powerful; for the first regulus (D), as well as that which is highly depurated, occasions these tinges. This great richness of colour agrees well with the idea of a large quantity of matter in a small bulk.

Volatile alkali dissolves nickel, and the solution is blue; the fixed alkali dissolves very sparingly, and forms a yellow solution.

(c) In proportion as nickel is more pure, it is the more difficult of fusion, so that when at its great degree of purity it requires for fusion nearly as great a degree of heat as forged iron: it is easily fused with other metals, but its scarcity has prevented us from examining the phenomena arising from hence. In general, however, we may remark, that the impure regulus cannot unite with silver: this must be attributed to the cobalt which it contains; for when well freed from that metal, it easily unites in equal proportions with the silver, and that without any remarkable diminution either of whiteness or ductility. This mixture, fused with borax, tinges it of an hyacinthine colour. Copper unites more slowly with

with depurated nickel, yielding a red and ductile metallic mass, which tinges borax of a reddish hyacinthine colour. With an equal or even a greater bulk of tin, nothing is produced but a brittle mass; in which respect also nickel differs from cobalt. It could not be amalgamated with mercury by trituration. Depurated nickel melts with tin, and forms a brittle compound.

It may seem doubtful, whether nickel is to be enumerated among the ductile or the brittle metals. Iron, when fused, is almost always brittle, so that its ductility, when united with nickel, is very remarkable.

(D) Depurated nickel is with great difficulty calcined in the ordinary way in the assay-furnace, and assumes only a brown colour; but by means of nitre it is more completely dephlogisticated, and becomes green. The metallic calx, vitrified with borax, produces an hyacinthine tinge, which yet, if occasioned by a regulus not well depurated, vanishes on continuing the fire, the glass remaining being altogether colourless, and upon the addition of nitre only a slight blue tinge is produced. A calx of well-depurated regulus of nickel forms a permanent colour. The calx of nickel communicates also to microcosmic salt an hyacinthine colour, which, by long-continued fusion on charcoal, may indeed be weakened; but hardly entirely discharged: this colour, on
the

the addition of nitre, changes to a violet, and on increasing the quantity of microcosmic salt, becomes again hyacinthine. If the calx of nickel be added to saturation, the fused glass appears of a blood colour, but upon cooling grows more and more yellow.

A R S E N I C

ARSENIC is found in the bowels of the earth, either in a metallic form or combined, or finally, sublimely, and in the way of solution, united with sulphur. This diversity could not escape the first discoverers, and hence their opinions concerning its true nature were strangely conflicting for a long time. We are chiefly ignorant as to what time it began to be distinguished from other minerals, and when it received the name which it still continues to bear. It is extremely probable that this substance was first discovered by those who were engaged in the search and taking of ores, believing itself to be

DISSERTATION XXI.

O F

A R S E N I C.

§ 1. *Historical Introduction.*

ARSENIC is found in the bowels of the earth, either in a metallic form or calcined, or finally, intimately, and in the way of solution, united with sulphur; this diversity could not escape the first discoverers, and hence their opinions concerning its true nature were strangely contradictory for a long time.

We are entirely ignorant at what time it began to be distinguished from other minerals, and when it received the name which it still continues to bear. It is extremely probable that this substance was first discovered by those who wrought in the roasting and fusing of ores, betraying itself by its white

white smoak, its garlic smell, and its pernicious effects in depraving metals and destroying animal life. Aristotle mentions the *Σανδαράχη*; and his disciple Theophrastus Eresius speaks of *Αρρενικος*, which was called *Αρρενικος* by Dioscorides and others, who lived about the beginning of the Christian æra. But these denominations comprehended only those minerals which by Pliny, and other Latin authors, are called sandarach and orpiment. Avicenna, a chemist of the eleventh century, who, so far as we know, was the first who distributed minerals into stones, metals, salts, and sulphurs, not only speaks of white arsenic, but, what is remarkable, of its sublimate. Theophrastus is the last who mentions the regulus, although he had before referred sandarach and orpiment to the metallic stones. It is unknown who first reduced white arsenic to a metallic form. Paracelsus, in his Manual, asserts that arsenic, sublimed with lime of egg-shells, becomes like silver; and in the year 1675, Lemerî described a method of subliming arsenic with fixed alkali and soap; but in the year 1649, J. Schroder mentions the regulus eliquated from arsenic or orpiment by means of white flux, charcoal-dust, and iron: he quotes Clossæus, but does not give the title of the work. In the *Pharmacopœia* 1644, this process is not to be found.

Avicenna, and many after him, even to our times, place arsenic among the sulphurs: Albertus Magnus and others, among the saline bodies; Beecher considers it as a soap, or a saline sulphureous body. Indeed, as white arsenic is soluble in water, it is plain that it contains something saline, although no appearance of such a thing can be discovered either in the regulus alone or in its mineralized state. That this saline substance is of an acid nature, plainly appears from its ready union with alkalis, especially as the celebrated Macquer's experiments shew, that neutral crystallizable salts may be generated from thence; but until our countryman Mr. Scheele's time, no one had been able to extract this acid in its pure state, and the ingenious inventor has lately described the method he pursued.

As to the sulphureous nature of arsenic, which some persons strenuously insist upon, it must be confessed that the regulus itself, nay even orpiment and realgar, are inflammable; a circumstance which however does not take place with respect to white arsenic. If therefore the sulphureous quality is to be determined from a single property (in the same way as the saline) it appears that it is only competent to arsenic in a certain state. But besides arsenic, zinc and several other bodies, which are easily inflammable, are not however from thence to be denominated sulphureous,

phureous, unless we will confine that appellation to the quantity and connexion of phlogiston adapted to inflammation.

It is commonly said that arsenic mineralizes metals, and therefore it is considered as a sulphur by some, who yet extend the idea of mineralization so far, as under it to comprehend all mixtures, whereof a metal forms a part : but if we examine this signification a little more accurately, we shall easily see that it is extended too far ; for if this be admitted, we must at the same time allow that no native metal is to be found ; thus the gold, which is called native, is scarce ever perfectly pure, but is mixed more or less with silver or copper. In the same way silver is mixed with gold or copper ; platina with iron ; copper with gold, silver, or iron ; nickel with cobalt, &c. If therefore arsenic, which, unless in its reguline state, never dissolves other metals (§ VI. A), be considered as a mineralizing substance, what hinders us from saying that gold is mineralized by silver and copper, and in general every metal mineralized by another ? Beyond doubt, the same reason holds good in all. With much less appearance of truth can we say, that metals are mineralized by earths, as these latter are scarce ever, except mechanically, mixed with the ores.

It is much more conformable to reason and experience, to call those metals mine-

ralized which are dissolved, and actually concealed by a menstruum. Sulphur is the chief agent employed by nature for this purpose; and although the acids of vitriol, of nitre, of phosphorus, and sometimes even the aerial acid, occasion the metals to put on an appearance foreign to their nature, yet the number of these is so small, that, compared with the sulphurated minerals, they almost vanish.

But the idea of a mineralizing arsenic, perhaps, is to be sought for further. This mineral, so troublesome to the mineralogist, occasioned the alchemists to suspect the existence of a certain arsenical principle indispensably necessary to the perfection of every metal; a suspicion occasioned by their strenuous endeavours, during the process of their great work, to discover, by the most subtle ratiocinations, the true composition of metals. Even so late as the year 1773, the Royal Academy of Sciences at Berlin proposed the following problem: *Quid arsenico in mineris præsente efficiat natura? Num idoneis evinci queat experimentis quod metalla re vera perficiat? Et si ita, quomodo & quousque hoc fiat?* The premium was adjudged to the answer of the celebrated Monnet, in which he, with great ingenuity and truth, considers arsenic as a semi-metal differing from all others; which is so far from constituting an essential part of the texture of metals, that it unquestionably is often totally absent,

absent, and when present, is always attended by inconveniencies, either carrying it off in its departure, or spoiling the mass. Certainly good copper is, though not without difficulty, eliquated from the grey ore; and silver, equally perfect, is obtained from the vitreous as from the red ore. No one as yet has been able to perfect any metal by means of arsenic, and if it be accidentally found mixed with others, it no more contributes to their goodness, than the lead in galena is useful to the silver, or the silver to the lead. If recourse be had to an arsenical principle so subtle as to evade the observation of our senses, let us leave that subject to be discussed by its authors.

All these considerations, however just, do not prevent us from asserting, that the acid of arsenic, like other acids, is a mineralizing substance, when at any time, in a disengaged state, it meets with a metal in the bowels of the earth, and in that form unites with it.

Among the chemists who have laboured during this century to discover the properties of arsenic, the celebrated Brandt must not be omitted, he being either the first who observed many of them, or at least the most accurate in their description. Mr. Pott has published a learned treatise on orpiment; J. G. Lehman, another on the sandarach of

the ancients; and many other books there are upon the same subject.

§ II. *Reguline Arsenic.*

Arsenic is found in a metallic form, in Bohemia, Hungary, Saxony, Hercynia, and elsewhere, but particularly at St. Marieaux mines in Alsatia, where not long since many hundreds of it were extracted. In Germany it is called Schoerbencobolt, and frequently Fliegenstein or Muckenpulver, but for what reason I know not, as it is not soluble in water, and therefore, unless when dephlogisticated, is not at all proper for the purpose alluded to by the name; perhaps by spontaneous calcination it becomes so much dephlogisticated as to acquire a degree of solubility.

As to its form, it is often found shapeless, friable, and powdery, but sometimes compact, divided into thick convex lamellæ, with a needle-formed or micaceous surface. It admits of a polish, which yet is soon lost in the air.

When fresh broken, it appears composed of small needle-like grains, with a leaden colour, which yet soon grows yellow, and by degrees blackish: in hardness it seems to exceed copper, in brittleness to equal antimony.

A regulus

A regulus may also artificially be procured from white arsenic, either by subliming it with oil, black flux, or other phlogistic additaments; or fusing it with double its weight of soap and pot-ashes; or, finally, precipitating it by some other metal from orpiment or sandarach, fused with sulphur and fixed alkali. That which is obtained by the first of these methods has a crystalline form, more or less regular, octaedral, pyramidal, or even prismatic. Sometimes the artificial regulus is sold in thick cakes; its specific gravity is 8,310, and therefore a cubic inch weighs about 43,19 drachms avoirdupois.

The mineral commonly called mispickel, is justly reckoned a regulus, as, when totally deprived of sulphur, it consists of arsenic and iron united in a metallic form; and although the latter amounts to $\frac{1}{2}$, or sometimes even to $\frac{2}{3}$, yet the compound is not magnetic: this, when ignited, sends forth an arsenical smell, and is thus soon rendered magnetic, although the operation be performed on a tile, without any phlogiston: it easily flows in the fire, and in close vessels the greater part of the regulus of arsenic rises, leaving the iron at the bottom; a compound of this kind may also be artificially made.

Reguline arsenic is far more volatile, and loses its phlogiston more easily, than any other metal, and therefore it cannot be fused,

fused, as for that purpose a greater degree of heat is necessary than what is sufficient to calcine, volatilize, and inflame it. In open vessels it begins to send forth a visible smoke, in a degree of heat = 180° of the Swedish thermometer: in order to inflame it, the regulus must be dropped into a vessel of a proper degree of heat, for if the heat be gradually increased, the metal is volatilized; the necessary degree must therefore be instantaneously applied. The flame is of an obscure whitish blue, diffusing a white smoke, and a garlic smell; in close vessels it retains its metallic nature, and exposed to the fire is sublimed in a determinate figure.

§ III. *Habits of Reguline Arsenic mixed in the Via Sicca with other Substances.*

(A) Arsenic in a reguline form, added to metals in fusion, melts with many of them, but thereby those which were malleable become brittle: such of them as flow with difficulty when alone, become more fusible by means of arsenic; but those which soon liquefy (at least tin) become more refractory: those which are yellow or reddish are made whiter, according to the quantity of arsenic; and such as are white acquire a grey colour, tin excepted, which by this means acquires a permanent and shining whiteness, and

and by fusion is able to retain $\frac{1}{2}$ its own weight; nor does it spoil the colour of platina when united with it. Gold fused in a close vessel takes up scarcely $\frac{1}{80}$, silver $\frac{1}{4}$, lead $\frac{1}{8}$, copper $\frac{1}{8}$, and iron more than its own weight. Iron, by means of a large quantity of this metal, loses its magnetic power, but it is difficult to determine exactly how much is sufficient for this purpose (as some of the iron always enters the scoria); but undoubtedly less than an equal quantity is sufficient. Bismuth retains about $\frac{1}{11}$, zinc $\frac{1}{4}$, regulus of antimony $\frac{1}{4}$, and manganese an equal quantity. Nickel and cobalt receive some arsenic, and that not a little; but the quantity can hardly be determined, as these metals are scarce ever got pure. Regulus of arsenic, in a sufficient degree of heat, and by triture of several hours, actually takes up $\frac{1}{6}$ of its own weight of mercury, and forms a grey amalgam.

By means of heat in an open vessel the arsenic may be again expelled, but flying off it generally carries with it some of the metal with which it is united, gold and silver not excepted, if the degree of heat be great and suddenly applied; yet platina perfectly resists the volatilization, nay, being very difficult of fusion, it even retains a portion of the arsenic.

(B) Regulus of arsenic cannot be united by fusion with alkaline salts until the phlogiston is sufficiently diminished; if, therefore,

fore, the regulus be added to nitre in fusion, after detonation they both easily unite, and the compound comes out exactly similar to that made with white arsenic (§ vi. B).

(c) Regulus of arsenic, exposed to distillation with the dry acid of arsenic (§ v.), sublimes before it can be acted upon by the acid, which must be first melted; but the regulus, when put into the acid in fusion, soon takes fire, and sends forth a white smoke; for the acid, being deprived of its phlogiston in this instance, separates that principle from the regulus, and takes it to itself in such quantity as to regenerate white arsenic; and on the other hand, the regulus, by means of the fire, is so far spoiled of its phlogiston, as to appear in the form of a calx.

(d) This regulus, in distillation with corrosive sublimate, yields a smoking butter, with a small quantity of mercurius dulcis and quicksilver. In this case the principles are changed; by means of a double elective attraction, the regulus of arsenic yields its phlogiston to the base of the corrosive sublimate, which being thereby really calcined, is reduced into perfect mercury, while the marine acid takes up the calx of the arsenic.

(e) Sulphur easily dissolves the regulus; and by fusion and sublimation yields yellow or red compounds, according to the different proportion (§ x. B). Hepar sulphuris

phuris takes up the regulus; but this last adheres to it so loosely, that it is precipitated by every other metal which can unite with the hepar.

§ IV. *Habits of Regulus of Arsenic, united by the Via humida with other Substances.*

(A) Water alone has no effect in this case.

(B) Vitriolic acid does not attack the regulus, unless concentrated and assisted by fire. The inflammable part of the regulus phlogisticating the acid flies off, so that the remaining part assumes the nature of white arsenic, and with menstrua exhibits the same properties as any other metallic calx.

The same is true of nitrous acid, except that it attracts the phlogiston more vehemently.

Marine acid has scarcely any effect, unless when boiling.

Acid of arsenic, which shall be spoken of hereafter (§ v.), by digestion changes the regulus into a white calx, and is itself altogether changed (by means of the phlogiston which it has taken) into a calx, provided the phlogiston be in due quantity.

The other acids I pass over, as entirely refusing to unite so long as the reguline form remains; for no metal, except when more or less deprived of phlogiston, can be dissolved

dissolved in acids. This impediment is very easily removed by the nitrous acid, but very difficultly by marine, as it abounds in phlogiston itself. In this case, therefore, the same compounds are produced with the regulus, as those with white arsenic, described in § VII. C.

It must here be observed, that solutions of the native regulus always yield a Prussian blue with phlogisticated alkali; which evinces the presence of iron.

Besides, it is to be observed, that the regulus plainly precipitates certain metals dissolved in acids, such are gold and platina in aqua regia, and also silver and mercury in vitriolic or nitrous acid. The silver generally appears in beautiful polished spiculæ, like the Arbor Dianæ; but if the arsenic be suffered to stand long in the nitrous solution, but little diluted, the silver spiculæ are again dissolved, the arsenic becoming in the mean time dephlogisticated. Solutions of bismuth and antimony are but obscurely rendered turbid.

Arsenic and iron naturally united, as in the mispickel, may be separated by digestion with marine acid or aqua regia; for the former menstruum in this way only attacks the iron; and the latter, although it can dissolve both, yet is not able to touch the arsenic so long as any iron remains. In order, however, that all the arsenic may remain alone at the bottom, a very subtil
pulverization

pulverization is necessary, together with a just quantity and strength of the menstruum, and heat must also be carefully avoided.

(c) The alkalis operate more slowly in the humid than the dry method, as, before a real union takes place, the phlogiston must be diminished. A saline hepar, by boiling, attacks the pulverized regulus; for that which is precipitated by an acid, yields by sublimation a true orpiment.

(d) The fatty oils, when boiling, dissolve the regulus, and form a black mass of the consistence of a plaster.

§ v. *Calcined Arsenic.*

The regulus, with a very gentle heat, loses so much of its phlogiston that it flies off in a white smoke; yet all the metallic calxes retain much of their inflammable principle, although not sufficient to give them a metallic appearance. The following experiments will plainly shew, that this is true also of arsenic:—Let calcined arsenic, moistened with nitrous acid, be exposed to heat, and a copious red vapour will break forth, which, collected, exceeds the arsenic four or five times in bulk; and, upon examination, is found to be no other than that which by the celebrated Priestley is called nitrous air; however, this always abounds in phlogiston, and scarcely contains any thing else, except a small portion of nitrous

trous acid, dilated into an elastic fluid by the abundance of phlogiston. In this case the inflammable principle can be derived from no other source than the arsenic; and we shall soon have occasion to take notice of other proofs.

The native calx of arsenic occurs but seldom in Saxony and Bohemia; but is found copiously in those places where the ores of cobalt are roasted, and is collected in the long and winding wooden tubes used in that operation. This smoke is found so loaded with phlogiston, that it appears grey; but is soon made white by sublimation, either with or without pot-ashes. This calx is volatile, but less so than the semi-metal itself, for it requires at least a degree of 195° . If in a close vessel it be raised by a fire a little higher, it becomes pellucid like glass. In the air its surface soon contracts a white opacity; but that which is found crystallized in the bowels of the earth, is not subject to this change. The specific gravity of white arsenic is 3,706, and that of the glass about 5,000.

It slowly excites upon the tongue an acid subdulcid taste.

White arsenic is in reality nothing else but an acid different from all known acids, and loaded with such a quantity of phlogiston as is sufficient to coagulate it. 100 parts of white arsenic contain at least 20 of phlogiston; and whatever is capable of separating

parating so much, is capable of leaving the acid pure. This acid (which has been examined particularly in another place) is of itself fixed, but when made red hot decomposes the matter of heat, gains phlogiston from thence, and regenerates white arsenic, which, loaded to saturation with phlogiston, becomes reguline. The dry acid, exposed to a moist air, deliquesces and falls totally into a limpid liquor, containing so much water as is necessary to the solution of the acid in a moderate temperature, that is $\frac{2}{3}$ of its own weight.

It is highly probable that all the metals are only different acids coagulated by a large quantity of phlogiston, although the connection of those principles is so close that we are hitherto ignorant of the means of separating them. The metallic calxes always contain more or less phlogiston, and most of them also contain aerial acid, which they take from the surrounding air in place of their lost phlogiston, and pertinaciously retain it; yet some calxes seem always to be free from that acid, although precipitated by aerated alkali: it is also certain that white arsenic is free from it. But this doctrine will be more fully illustrated in another place. In the mean time it appears from hence what opinion is to be formed of the salts and sulphurs of metals, although the ideas of the ancients upon this subject occasion much obscurity.

Hence also it appears why earths and metallic calxes fix arsenic. Nickel and cobalt generally abound with arsenic, which cannot be expelled by calcination alone; for when a great part is dissipated by the force of the fire, the rest either gradually loses its phlogiston and adheres like a fixed acid, or is united by fusion with the metallic earths; but powder of charcoal being added during the calcination, immediately a large quantity of smoke breaks forth, which smells like garlic, and is nothing else but the arsenical acid reduced by phlogiston to the form of a calx.

§ VI. *Properties of calcined Arsenic mixed by the Via Sicca with other Substances.*

(A) White arsenic fuses with the same metals as the regulus does, but in a manner somewhat different: it is true that no calx, as such, can be united with metals; but nevertheless the calx of arsenic added to them, when fused in a crucible, readily unites with them; but let it be remembered, that it is reduced by the phlogiston of the fused metal; therefore, when the metal is an imperfect one, scorix also arise, consisting of the calcined part of the metal and white arsenic.

(B) White arsenic injected into fused nitre excites a violent intumescence and effervescence, but without any scintillation; if this addition be continued until a new portion

portion excites no motion, and the mass be then well fused, the product is called arsenic fixed by nitre. During this operation the nitrous acid is volatilized by the phlogiston of the metallic calx, and the arsenical acid, being disengaged, unites with the base of the nitre; however, crystals are not obtained, because by means of the vehemence of the fire the alkali is superabundant; but by a just proportion of alkali and a due degree of heat crystals may be produced; for the vegetable alkali requires a slight superabundance of arsenical acid in order to produce crystals; this necessary superabundance may also be preserved in a crucible, provided the fire be so regulated that the bottom may be scarcely red; it succeeds better however in distillation.

The residua of the distillations, performed with an equal portion of prismatic, cubic, or flaming nitre, all yield arsenicated alkali, which, after solution in water, may be crystallized. It is vulgarly supposed that these crystals cannot be decomposed by other acids, but erroneously. It is evident that though upon the addition of another acid the alkaline base unites with it, yet the acid of arsenic, being itself soluble, will yield no precipitation, nor even occasion a turbidness; from the want of turbidness nothing as yet has been estimated but the cohesive force of the compound: but the error arises from hence, that chemists have supposed

that white arsenic enters those salts, when in reality it is only the acid. Therefore, in order the more clearly to discern the event, we should dissolve the arsenicated vegetable alkali (the neutral arsenical salt of Mr. Macquer) in vitriolic acid; this being done, let the neutral salt be precipitated with highly-rectified spirit of wine, and washed, which is very easily done, for the vitriolated vegetable alkali is not at all, and the arsenicated vegetable alkali, but very sparingly, soluble in this spirit. The salt separated in this manner from the disengaged acid is soon distinguishable, and in this instance exhibits all the properties of vitriolated vegetable alkali: this, therefore, is undoubtedly a decomposition of the arsenical salt by way of solution; here the alkali has no effect, as it is itself unable to precipitate. But the nature of these salts will elsewhere be more accurately examined.

The digestive salt, common salt, and sal ammoniac, are not changed by arsenic; the reason of which undoubtedly is, that the marine acid is naturally loaded with phlogiston.

(c) Corrosive sublimate, distilled with white arsenic, ascends unchanged, whatever proportions be employed. Mr. Pott long since observed, that in this case no butter of arsenic arises; and certainly no such can arise, as the calx of arsenic attracts the marine acid with less force than the calx of the mercury

mercury does. Let butter of arsenic mixed with calx of mercury be exposed to distillation; at first, before the whole can be decomposed, a little of the butter is elevated, but soon after a corrosive sublimate rises, and finally a white arsenic.

(D) Fixed alkali with white arsenic melts in the fire almost in the same way as nitre, only the phlogiston flies off more slowly. Caustic vegetable alkali, ignited in a close vessel, fixes about double its quantity of white arsenic; but the mineral alkali fixes nearly triple. Caustic volatile alkali, drawn from white arsenic to dryness two or three times repeatedly, becomes at length so closely united to it that the mass bears fusion by means of fire.

Terra ponderosa and calcareous earth, spoiled of the aerial acid by roasting, retain, on ignition in close vessels, about an equal quantity of arsenic; but magnesia, pure clay, and siliceous earth, scarcely any.

(E) Sulphur easily unites with white arsenic, reduces and mineralizes it; hence this compound always diffuses a most penetrating odour of volatile vitriolic acid; for a portion of the sulphur yields to the calx of the arsenic a great quantity of phlogiston. See also § VIII. IX. and X.

Saline hepar also dissolves white arsenic, but more readily attacks the regulus.

Equal quantities of sulphur, crude arsenic, and white arsenic, unite by fusion in a

close vessel, and generate the *lapis de tribus*, which is also called pyrmison or arsenical magnet; this is red and sometimes transparent.

§ VII. *Properties of calcined Arsenic mixed by Solution with other Substances.*

(A) 80 parts of distilled water, in an heat of 15° , dissolve one of white arsenic, and when boiling 15 parts of water are sufficient. But the arsenic, when once dissolved, is more easily retained than taken up; so that in a moderate heat 15 parts can hold one suspended a long time; the same is true of the other solutions. Solution of arsenic changes the deep tincture of turnsole to a red colour, but, like other metallic solutions, makes syrup of violets green; it is not changed by neutral salts, but is precipitated by most metallic salts, and that in such a way that the metallic calxes, united with the arsenic, fall (though slowly) to the bottom.

It may be asked, whether the whole of the arsenic, or only the arsenical acid, unites with the metallic calx, yielding the phlogiston to the menstruum of the other metal? Certainly such a mutual commutation of principles does not appear improbable, if we consider only those cases in which the menstruum is vitriolic or nitrous acid; but as iron (for example) united with marine acid (which does not attract the phlogiston of
white

white arsenic) as well as when it is joined to nitrous acid, is precipitated, it would appear that the whole of the arsenic is united, at least in certain cases, to the metallic calxes.

(B) 70 or 80 parts of spirit of wine, by means of a boiling heat, dissolve one of arsenic.

(C) Concentrated vitriolic acid, boiled with white arsenic, dissolves a small portion of it, which yet upon cooling it again deposits in the form of crystalline grains: this vitriol dissolves in water with much greater difficulty than white arsenic itself; exposed to the flame of a blow-pipe, it soon emits a white smoke, but at the same time is formed by fusion into a globule, which at first bubbles, but soon grows quiet, and although of a white heat is but slowly consumed: the white arsenic quickly flies off, not being capable of enduring fusion, and much less ignition.

If the affused acid be evaporated to dryness, the repetition of this operation fixes the arsenic more and more, by carrying off the phlogiston, but scarcely exhibits the arsenical acid pure.

The same thing happens with the nitrous acid; when diluted it dissolves the calx, which on crystallization appears nearly under the form of white arsenic, but in its nature is a true middle metallic salt, which is difficultly soluble in water, and exposed to flame upon charcoal exhibits the same phenomena.

na with those exhibited by the vitriol of arsenic above mentioned, but is consumed somewhat more quickly.

Concentrated nitrous acid deprives the calx of its phlogiston more effectually; and by a proper quantity, if evaporated to dryness, the calx may be brought to such a state that the acid alone shall remain. That substance which is commonly called gum of arsenic, is nothing but arsenic more or less dephlogisticated, but always more so than white arsenic.

The marine acid contains phlogiston as one of its principles, it therefore attacks white arsenic in a different way: when concentrated and boiling it dissolves $\frac{1}{3}$ its own weight, of which no small portion again spontaneously separates upon cooling, but is saturated with marine acid. This salt, which may also be had in a crystalline form, is much more volatile than the former, nor does it by any means endure ignition; in a close vessel it all readily sublimes, and is sparingly soluble in boiling water (§ IX. D.). This solution is of a fine yellow, and scarcely differs from butter of arsenic except in its degree of concentration. The very nature of marine acid prevents the acid of arsenic from being disengaged by its means; which yet is easily made to appear, if to a solution of white arsenic in boiling marine acid, be added double the weight of nitrous acid; the liquor being then evaporated

rated to dryness, the arsenical acid will remain, which, in order to free it from any foreign acid, should be urged by fire until it begins to be ignited: by this method 100 parts of white arsenic yield about 80 of dry acid. In this operation the nitrous acid acts more readily upon the phlogiston of the white arsenic than when it is poured on the powdered arsenic; as in the former case the solution effects a more perfect division of the arsenic: hence it also appears why white arsenic is dissolved in greater quantity, and without any subsequent crystallization, by aqua regia than by any other acid.

The phlogisticated alkali precipitates metals dissolved in acids, yet leaves arsenic nearly untouched, both in vitriolic and nitrous acids, and in aqua regia; which happens either from the small quantity of the matter dissolved, or from its nature being changed. From the marine acid it separates arsenic of a white colour: in this case error is carefully to be avoided, for the solution may be precipitated by water alone, unless the quantity of marine acid be large; besides, the disengaged alkali, which is frequently found in this lixivium, must be saturated by the acid.

Marine acid is dephlogisticated by digestion with manganese, and is resolved into a red vapour, which in a close vessel spoils a certain quantity of white arsenic, dissolved in water, of its inflammable principle, so that
the

the vessel is found to contain separately water, acid of arsenic, and marine acid regenerated; the first of these may be obtained alone by evaporation to dryness.

The power of the other acids upon arsenic has not yet been sufficiently examined. The acids of arsenic and of fluor dissolve it, and form crystalline grains; and that sedative salt has the same effect I hardly entertain a doubt; although it must be confessed that borax, which is saturated with that acid, does not precipitate arsenic dissolved in water. The acid of sugar easily takes up white arsenic, and yields prismatic crystals; the same is nearly true of the acid of tartar: vinegar, and the acids of ants and of phosphorus, also attack it, and yield crystalline grains, which are scarcely soluble in water, nor have they yet been found to contract any union with that fluid in the way of deliquescence.

From what has been said it appears plainly, that solutions of arsenic made in acids, in certain cases depart from their usual nature; which we have already shewn to be owing to the adherence of the phlogiston being so loose that the acid of arsenic is readily set at liberty.

(D) The fixed alkalis dissolved in water take up white arsenic; and if by means of heat they be loaded with it, a brown tenacious mass is produced, which acquires solidity, is of a disagreeable smell, and is called
hepar

hepar arsenici. The arsenic is partly precipitated by mineral acids, though a portion of it gradually loses its phlogiston and adheres more tenaciously.

A solution made with volatile alkali seems to effect this decomposition more readily, as no precipitation is occasioned in it by acids.

(E) A limpid solution of saline hepar, dropped gently into a solution of white arsenic, floats, forming upon the surface a grey stratum, which at length disturbs the whole of the liquor.

(F) White arsenic, dissolved in water by the assistance of heat, attacks some metals, particularly copper, iron, and zinc, nay the two last solutions yield crystals by evaporation. These compounds are not visibly changed either by acid or alkaline substances. Volatile alkali does not discover the copper by a blue colour, nor in the martial solution does phlogisticated alkali occasion any blue sediment. The cause of these phænomena is to be sought for in the superabundance of phlogiston: for the acid of arsenic takes up all metals; united with copper it is dissolved by the volatile alkali with a blue colour, and joined with iron it exhibits Prussian blue in the usual way: the phlogiston which coagulates the acid into white arsenic, is the substance which in these mixtures constitutes the only material difference.

§ VIII. *Mineralized Arsenic.*

We have already observed that arsenic, both reguline and calcined, may be united with sulphur (§ III. VI). Nature spontaneously produces these mineralizations yellow or red, sometimes pellucid and crystalline; the yellow seem to affect a lamellated form, the red a prismatic.

In the roasted heaps of arsenical ores, there frequently are found beautiful crystals, partly tetradral, partly octaedral, some of which are hollow pyramids trigonal or tetragonal, each triangle being composed of filaments respectively parallel to the sides: thus an hollow trigonal pyramid, frequently filled up with lesser pyramids continually decreasing in size, forms a tetradrum; but 8 tetradra, properly disposed, form an octaedron. Thus in the *via sicca* is formed a structure entirely similar to that which common salt, digestive salt, and perhaps all others, assume in the way of solution.

Iron at the same time entering these mineralizations, renders the colour white, together with a polished and metallic appearance. To this class belong the ores, which are commonly called white or arsenical pyrites. Arsenic with sulphurated silver forms the red ore of silver, and with sulphurated silver and copper, the white or grey

grey ore of silver; it appears to be only mechanically mixed with the crystallized ores of tin, and the calcined ores of cobalt.

The specific gravity of orpiment is 5,315, but that of realgar about 3,225.

Orpiment and realgar sublime totally in a gentle heat, unless they be mixed with other substances; yet they sustain fusion, and the former of them is thence made red. The arsenical pyrites yields a sublimate more or less white, in proportion to the quantity of sulphur; but the greater part of it does not sublime, but remains at the bottom.

§ IX. *Properties of mineralized Arsenic mixed by the Via Sicca with other Substances.*

(A) Of those metals which readily unite with sulphur and arsenic, a certain quantity may be united with orpiment and realgar. We have already mentioned the stone called pyrmison (§ VI. E), and many other ores of this kind (§ VIII.), which may also be artificially imitated. Silver, mineralized by fusion with orpiment, yields the red ore of silver. The rest may be formed still more easily.

(B) Nitre is alkalized by mineralized arsenic, for it detonates partly with the sulphur, partly with the arsenic, which when mineralized is always found in a form nearly reguline.

reguline. The alkali thus disengaged, either forms a sal polychrest with the acid of the sulphur, or unites intimately with the arsenic (§ VI. D).

(C) Fixed alkali, added in proper quantity, either to orpiment or realgar, and exposed to a subliming heat, fixes the sulphur, but discharges the greatest part of the arsenic; yet the hepatic mass retains a small quantity of it, and if the alkali abounds, scarce any of the arsenic rises.

(D) Orpiment, on distillation with double or triple its quantity of corrosive sublimate, yields two liquids which refuse to mix; at length, on increasing the heat, a cinnabar arises. In the recipient, a butter of arsenic is found at the bottom, pellucid, of a ferruginous brown, which in the open air at first sends copiously forth a visible white smoke, and attracts the moisture of the atmosphere, by which it is gradually precipitated. The genesis of the butter has been already explained (§ III. D; VI. C); it is very remarkable that it unites with marine acid so slowly, that they seem to repel one another, nor can they be made to unite beyond a certain degree. Distilled water added to the butter precipitates a white powder, which though ever so well washed, retains somewhat of acidity; for a portion of butter of arsenic is yielded on distillation; a circumstance which is also true of Algarotti's powder. The smoke affects the organ of smell.

smell with a peculiar penetrating odour, somewhat resembling that of phlogisticated vitriolic acid, and deposits white flowers.

The supernatant liquor, which authors compare to oil, is yellowish and pellucid; with water and spirit of wine it quickly separates a white arsenical powder; is not disturbed by the stronger acids; with alkalis it effervesces, and is precipitated. If it be kept in a cucurbit with a long neck, and unstopped, white flowers gradually concrete round the orifice; these are lax, and sometimes approaching to a crystalline form. Finally, by spontaneous evaporation pellucid crystals appear at the bottom of the liquor, which are very difficultly soluble in boiling water, but when dissolved, precipitate silver from nitrous acid, and on the addition of an alkali, let fall some arsenic. In lime-water a white cloud slowly surrounds them; exposed to the fire, they neither decrepitate nor lose their transparency, but totally sublime without any arsenical smell, which yet immediately appears, if ignited phlogiston comes into contact with them. No traces of mercury appear in this liquor, either by alkali or copper; undoubtedly, if any sublimate was present, it would remain in the water after the precipitation of the arsenic. Terra ponderosa, dissolved in marine acid, and dropped into this liquor, does not form even the slightest

slightest congrumation, so that there is no vitriolic acid present.

From what has been said it appears, that the supernatant liquor is no other than a very dilute butter of arsenic, which, on account of the water, contains less arsenic. The butter contains the acid in its highest degree of concentration, and therefore loaded with a larger quantity of arsenic; the former liquor will therefore be more abundantly obtained, if the mixture of corrosive sublimate and arsenic be set to stand a night in a cellar, or moistened with water, before it is subjected to distillation. As the common marine acid can dissolve only a determinate quantity of the butter, it follows, that what remains after compleat saturation should totally refuse to mix. Marine acid too much diluted precipitates the butter; but in proportion as it is stronger, it dissolves a greater quantity.

§ x. *Properties of mineralized Arsenic mixed by Solution with other Substances.*

(A) Water has no effect on mineralized arsenic.

(B) The acids operate according to circumstances, especially the nitrous acid and aqua regia; the former menstruum, if concentrated, soon destroys the red colour of realgar, but does not affect the yellowness of
of

of orpiment, for its primary action is to calcine the arsenic, which in realgar must necessarily change the red colour to a yellow.

Aqua regia, by long digestion, takes up the arsenic, but so as to leave the sulphur alone at the bottom; hence we may discover the proportion of sulphur to arsenic. But this operation must be skilfully performed, lest on the one hand, by the inertness or insufficient quantity of the menstruum, some part which should be taken away remain untouched; or, on the other, lest that portion which should remain entire be diminished. The colour of the residuum ought to be altogether grey, for so long as any yellow particles remain mixed with it, some of the arsenic also remains. By too much heat, or too long boiling, especially if the nitrous acid be strong, more or less of the sulphur is also destroyed; for the nitrous acid takes away the principle of inflammability from the vitriolic, so as to set the latter at liberty.

If iron be present in the mineralization, it is all dissolved in virtue of its superior attraction before the arsenic is acted upon, unless it be too much calcined during the operation, either by heat, by the access of air, or by the great power of the menstruum.

The red ore of silver is compleatly decomposed by aqua fortis, which takes up

the silver and the arsenic, so that the sulphur alone remains at the bottom; by this method, 100 parts of the transparent crystals yield about 60 of silver, 27 of arsenic, and 13 of sulphur; iron is not always present.

The white ore of silver, first treated with aqua fortis, lets fall the silver and copper, and then yields the remainder of the arsenic to aqua regia; so that at length the sulphur may be obtained pure: the dissolved silver may be precipitated by copper.

(c) Caustic fixed alkali, boiled in water with orpiment, yields a foetid hepatic solution, called by some a sympathetic ink.

Orpiment boiled in water, with double the weight of quick-lime, affords a liquor which may be employed for proving wines; in this case the *hepar calcis* operates. These solutions, upon the addition of acids, deposit both the sulphur and the arsenic.

(d) Oils too, assisted by heat, dissolve both orpiment and realgar.

§ XI. *Uses of Arsenic.*

Concerning the uses of this metallic substance, we can only treat in a very slight way.

It can hardly be doubted but that it may be applied to valuable purposes in medicine, and experiments have long since put that matter entirely out of doubt; but with respect

respect both to its dose and preparation, the utmost caution is necessary. From the properties disclosed by the foregoing experiments, it appears that this most virulent of all poisons acts in the manner of an highly corrosive acid, and that even externally (§ v.). Since then phlogiston and alkalis are the most powerful correctors of acid acrimony, it will readily occur how it may be mitigated, and its deleterious effects obviated. Hence too it appears why realgar is less noxious, why the regulus is milder than white arsenic, and this again milder than the dry acid; and why the baths of Carlsbad, which contain a mineral alkali only, united with aerial acid, are extremely useful in diseases occasioned by arsenic: why arsenic, taken internally without the necessary correction, occasions by its irritating quality convulsive motions, among other symptoms, both in the stomach and other parts of the body. To pass over other matters, which from the chemical analysis of arsenic might be useful in the practice of medicine, this only I add, that of all the metals arsenic most easily loses its phlogiston (§ II.); therefore we should be cautious in confiding to phlogistic correctors, as the phlogiston may be separated in the viscera by many different ways. The instance of a man poisoned by arsenic, who was dissected in the anatomical theatre at Upsal, shewed that the penetrating garlic smell may be

excited simply by a tendency to the putrefactive fermentation.

The *psilothrum turcicum* contains orpiment, among other substances; but its depilatory power is perhaps more properly ascribed to the caustic alkali.

Philosophers are wont to evince the extraordinary porosity of bodies, and the wonderful subtilty of vapours, by the sympathetic ink (§ x. c.); for writing made with vinegar of litharge, by itself invisible, exposed to the vapour of this liquor, becomes in a few minutes of a brown colour, even though a great many folds of paper be interposed.

Wines naturally acid, or grown so by age, still continue to be edulcorated by lead, notwithstanding the punishments attending the detection of this fraud: it is therefore of great consequence to be in possession of an easy method of discovering such a sophistication. For this purpose the probatory liquor (§ x. c.) is commonly employed; for this, when dropped into pure wine, occasions nothing but a yellow precipitate, but when the wine is adulterated, a brown or black. This may also be done by a saline hepar; but fraud and avarice have contrived methods of eluding this proof, unless chemistry lend its assistance; for if a small quantity of chalk be contained in the wine, the saline hepar fails, for the white calcareous earth falling, diminishes the blackness.

blackness. A large proportion of tartar, renders the probatory liquor ineffective, as the tartareous acid forms with the lime a white salt very difficult of solution.

Arsenic sometimes enters metallic compositions, especially copper and tin; but it is much to be wished that such compositions were banished, at least from the kitchen. Shot made of lead is sometimes hardened by orpiment.

Regulus of arsenic enters into the composition of Meuser's phosphorus. The power of the calx in vitrification was long since known to Geber, and therefore it is frequently employed in glass-houses, either for facilitating fusion, for acquiring a certain degree of opacity, or, finally, for carrying off phlogiston. The method in which mountain crystals, placed over orpiment, white arsenic, crude antimony, and sal ammoniac, mixed in a crucible, are tinged by means of heat, is described by Neri, and upon trial this is found to be true; I have thus obtained these crystals beautifully marked with red, yellow, and opal spots, but at the same time cracked, which could scarcely be avoided.

In painting too the artists sometimes employ arsenic. Painters in oil frequently use both orpiment and realgar; and it is probable that wood covered with a pigment mixed with white arsenic, would not be liable to be spoiled by worms. A most

beautiful green pigment may be precipitated from blue vitriol, by means of white arsenic dissolved in water, together with vegetable alkali; this, prepared either with water or oil, affords a colour which suffers no change in many years. The playthings of children, however, should not be painted with this or any other preparation of arsenic, on account of their custom of putting every thing into their mouths.

DISSERTATION XXII.

OF THE

ORES OF ZINC.

§ 1. *Historical Introduction.*

THE semi-metal, which at present is called Zinc, was not known so much as by name to the ancient Greeks and Arabians. The name which it bears at present first occurs in Theophrastus Paracelsus (*a*); but no one as yet has been able to discover the origin of this appellation. A. G. Agricola calls it contrefeyn (*b*); Boyle, spectrum (*c*): by others it is denominated specter, and Indian tin (*d*). Albertus Mag-

(*a*) In operibus, passim.

(*b*) De re metallica.

(*c*) Ponderab. flammæ.

(*d*) Fœda trifida chymica.

nus, more properly called Bolstadt, who died in 1280 (*e*), is the first who makes express mention of this semi-metal. He calls it golden marcasite, asserts that it approaches to a metallic nature, and relates that it is inflammable. However, as zinc is white, the name of golden marcasite is not very proper; it would therefore appear probable, that it derives that name from the golden colour which it communicates to copper, had not Albertus expressly said, that copper united with golden marcasite becomes white; but he has probably either misunderstood or misrepresented what he had heard related by others. It may also happen that zinc was formerly thought to contain gold. J. Matthesius, in 1562 mentioned a white and a red zinc (*f*); but the yellowness and redness are only to be understood of the ores. Hollandus, Basil Valentine, Aldrovandus, Cæsius, Cæsalpinus, Fallopius, and Schroeder, observe a profound silence on that head (*g*).

The eastern Indians have long since been in possession of the method of extracting pure zinc from the ore, at least, in the course of the last century. This metal was brought from thence to Europe. Jungius mentions the importation of zinc from In-

(*e*) In libro mineralium.

(*f*) Sarepta.

(*g*) Pott on Zinc.

dia, in 1647 (*b*): a metal of this kind, under the name of *tutenag*, is still brought from thence, which must be carefully distinguished from the compound metal of that name. G. E. van Lohneis tells us, in 1617, that a long time before zinc had been collected by fusion at Goslar (*i*). It has been long usual to form *orichalum* from the ores of zinc by the addition of copper; but it does not yet appear at what time this art was invented. Pliny makes mention of the *orichalum*, as also of three species of Corinthian vases, one of which is yellow, and of the nature of gold (*k*). Erasmus Ebner of Norimberg, in the year 1550, was the first who used the *cadmia* of Goslar for this purpose.

In the year 1721, Henckel indeed mentioned that zinc might be obtained from *lapis calaminaris* by means of *phlogiston*, but he conceals the method (*l*). The celebrated Anton. van Swab. in 1742, extracted it from the ores by distillation, at Westwick in Dalecarlia (*m*). It was determined to found a work for the purpose of extracting larger quantities of this semi-metal;

(*b*) De mineralibus.

(*i*) Bericht von Bergvercken,

(*k*) Hist. Nat. xxx. c. 2.

(*l*) Pyritologia.

(*m*) Elogium magni hujus metallurgi coram, R. Acad. Stock. recitatum.

but

but afterwards, for various reasons, this project was laid aside; therefore the illustrious Margraaf, not knowing what had been done by the Swedish mineralogists, in the year 1746 published a method of performing this operation, which he had discovered himself (*n*).

It is not known how zinc is extracted in China. A certain Englishman, who several years ago took a voyage to that country for the purpose of learning the art, returned safely home, indeed, and appears to have been sufficiently instructed in the secret, but he carefully concealed it. We find afterwards that a manufactory had been established at Bristol, where zinc is said to be obtained by distillation per descensum. We have already seen that it had been before obtained in Sweden by distillation per ascensum, which afterwards was effected in larger quantity, by Mess. Cronstedt and Rinman, two very celebrated mineralogists and metallurgists.

The difficulties occasioned by the volatile and combustible nature of this metal, for a long time retarded the knowledge of the ores containing it; nor is that wonderful, as, being of a metallic form, it has even to our times been considered as composed of two or three ingredients. Albertus Mag-

(*n*) Mem. de l'Acad. de Berlin.

nus thinks iron an ingredient ; Paracellus called it a spurious son of copper ; Leme-ry holds it to be a species of bismuth ; Glauber, and many alchemists, consider it merely as an immature solar sulphur ; Homberg, as a mixture of tin and iron ; Kunckel, as a coagulated mercury ; Schluter, as tin made brittle by sulphur, &c.

The ore, which resembles true galena, is called pseudo galena ; and is for that reason, perhaps, by the inhabitants, called blende, as in texture and splendor it resembles the blends, though it contains no silver. The celebrated Brandt, in 1735, shewed that this contained zinc (o) ; and soon after D. Swab actually extracted it from the Bolognian pseudo galena, which possesses a metallic splendor. The Baron Funch, in 1744, determined the presence of zinc in pseudo galena from the flame and the flowers (p) ; and in 1746 Mr. Margraaf set the matter out of doubt.

Zinc cannot be united with sulphur alone, yet is found joined with it in the pseudo galena ; and this conjunction Mr. Cronstedt (q) thinks is effected by means of iron ; but Mr. Sage (r) supposes that in this instance an earthy hepar is formed by means of lime.

(o) Act. Upsal.

(p) Act. Stockholm.

(q) Cronstedt Mineralog.

(r) Mem. de l'Acad. de Paris, 1771.

Julius, in the year 1570, undertook, at Rammelsberg, the preparation of a certain salt, which he called Ertz-alaun, but which we now meet with under the name of Gallizenstein. No one, before 1735, knew the true composition of this salt; but about that time D. Brandt published two observations explaining its nature; for he found that this salt calcined, and then treated with charcoal-dust and copper, formed brass; and also that zinc, directly dissolved in vitriolic acid, formed a salt of the same nature as gallizenstein. In the same year Mr. Hellot communicated the latter of these experiments, made by himself, to the Royal Academy at Paris, proving that white vitriol is a middle salt composed of zinc and vitriolic acid.

Mr. Sage has lately attempted the analysis of lapis calaminaris, in which he asserts that zinc is mineralized by marine acid. The same author contends that zinc is found in manganese (*f*); and Dr. Bayen relates that he discovered it in the white ores of iron (*t*): but they have both mistaken manganese for zinc (*u*).

(*f*) Mem. de l'Acad. de Paris, 1770.

(*t*) Journal de Physique, par Mr. Rozier, 1776.

(*u*) See the Treatise on the White Ores of Iron.

§ II. *Zinc is presented to us by Nature under a Variety of Forms.*

It is not yet certain whether zinc be ever found native, unless we suppose the grey, flexible, metallic, inflammable filaments, surrounded by yellow ochre, which Mr. de Bomare observed in the neighbourhood of Limburg and Rammelsberg, to be produced solely by the hands of nature (*). In order to discover their true origin, they must be attentively considered, and their nature solicitously investigated in the matrixes. In the mean time, it will be proper briefly to describe the habitudes of perfect zinc, when exposed to flame upon charcoal. This semi-metal scarcely melts alone by the blow-pipe, as its whole surface is quickly covered with a calcined crust; but the internal mass, fused and exposed to strong heat, now and then explodes with a beautiful greenish blue flame, and disperses a white calx.

A small piece of zinc is taken up with effervescence by microcosmic salt in fusion; at the same time it sends forth many flashes, with a crackling noise; but if the heat be too great it explodes, scattering about ignited particles.

(*) De Bomare, Mineralogie.

Borax takes up zinc with a degree of effervescence, and the fused regulus at first tinges the flame; if the blast be intermitted it sends forth a flash, and afterwards it is difficult to reproduce the phenomena; but the regulus is gradually diminished, and the mass of borax spreads upon the charcoal without any explosion.

The mineral alkali, exposed to heat with zinc, in a silver spoon, corrodes it, but without any tinged flame, or any explosion (y).

The ores containing zinc differ much in appearance and properties; but so long as the uncertainty of the existence of native zinc remains, they may, agreeably to their nature, be divided into two classes, some containing the semi-metal simply deprived of phlogiston, the others holding it mineralized, either by some acids, or united to sulphur by the means of iron.

Calcined Zinc.

(A) Pure zinc, calcined in discrete particles, is extremely rare. To this we may refer the zinc brought from China by Grill, and described by Von Engestrom in the year 1775 (z).

(y) The Chinese zinc, upon examination, yields scarcely half a pound of lead in an hundred. The zinc of Gollar contains somewhat more; but neither the one nor the other yields the smallest particle of iron.

(z) Aët. Stock. 1775.

That the comparison with native zinc may be more easily made, it will be necessary to describe briefly the habitudes of flowers of zinc, as examined by the blow-pipe. These flowers, exposed alone to the flame on charcoal, put on a phosphoric splendor, which vanishes when the flame intermits: they also remain fixed and refractory.

With microcosmic salt they are readily dissolved without spumescence: upon cooling, the globule remains transparent, if the zinc amounts to less than double the bulk of the salt; if to more, the globule is milky. In proportion as it is more saturated, it adheres the less to the charcoal.

With borax the same thing happens, but the flowers are more slowly taken up; and in proportion as the globule is more loaded, it expands more upon the charcoal.

In a silver spoon, with mineral alkali, they suffer no sensible change.

(B) Calcined zinc, mixed in various proportions with earthy and ferruginous particles, commonly called *lapis calaminaris*, is employed in the composition of brass: it is of a ferruginous, yellow, or white colour, and generally hard; but the hardness is not the same in all, nor is it sufficient to strike fire with steel.

These minerals exhibit with the blow-pipe the same phenomena as the preceding varieties, except those which abound in iron;

iron; for the subtile powders of these last, exposed to a white heat, are of a more obscure colour, and are magnetic (a). The microcosmic salt contracts with them the colour of smoked glass; borax a yellowish green; but in both cases, if too much ore be added, an opacity is produced. The mineral alkali grow black.

Mineralized Zinc.

Zinc assumes appearances foreign to its nature, in the hands of nature, partly by its union with a certain native acid, partly by means of sulphur. Among the acids which mineralize zinc, no other are yet known but the aerial and the vitriolic.

Aerated zinc is found concreted so hard, as sometimes to strike fire with steel; it exhibits an appearance like quartz, upon breaking, and is on the surface generally knotty, ramous, or variously contorted into lamellæ: this is called glass of zinc. And Mr. von Swab observed, during distillation, that a matter, exactly of the appearance above described, was produced through the smallest cranny in the apparatus.

A variety of this mineral, brought from England, exposed to flame with the blow-

(a) The celebrated Rinman, after calcining the white lapis calaminaris of Aix-la-Chapelle for the space of eleven days, in one of the furnaces used for the preparation of steel, found that it adhered to the magnet almost in the same manner as filings of iron.

pipe, remained without liquefaction, but cracked, was as it were resolved into flowers, and acquired a more dilute colour. The smell shews no traces of sulphur, nor is it magnetic either before or after calcination. The microcosmic salt, and also borax, dissolve it without difficulty; the latter somewhat more slowly. The mineral alkali scarcely takes up any, so that its habitudes much resemble those of the flowers.

Artificial vitriform zinc manifests the same properties as the natural, but does not split, and is more slowly and sparingly dissolved in the usual salts.

(B) To this class also must be referred the variety which is soluble in water by means of vitriolic acid. Mineralogists very properly enumerate this among the metallic salts; yet it must not be passed over in a place where our intention is to speak of all the minerals which contain zinc abundantly.

Pure vitriol of zinc, exposed to the flame, on fusion foams violently, and, finally, leaves behind a refractory mass, which does not grow phosphoric like the flowers.

This vitriol, calcined, is readily taken up with effervescence by the microcosmic salt: if too much of the vitriol be added, the globule is of an opal colour. The same takes place with borax. It unites at first with mineral alkali, with violent effervescence;

cence; but afterwards is very little acted upon.

Native vitriol of zinc is scarce ever found pure, but mixed with copper or iron, or both; so that the phænomena vary in respect both of the quantity and quality of the heterogeneous mixture.

Zinc, mineralized by sulphur, produces various colours. I have known it black, brown, yellow, greenish, and, finally, with a metallic splendor; which last is called by Mr. Cronstedt, particularly, the ore of zinc. The pseudo galena puts on a squamous form, not unlike that galena which shines when the little lamellæ are viewed obliquely. Sometimes it is found semi-transparent, very rarely octaedral; it occurs accidentally, mixed with silver, lead, copper, arsenic, and other metals.

The habitudes vary a little, according to the different heterogeneous matters. For example, we shall describe three varieties found in Sweden; *viz.* the black of Danneberg, the red of Sahlberg, and the metallic one of Boval.

The first of these does not strike fire with steel, yields a brown powder which decrepitates upon heating, sends forth a smoke of a sulphureous smell, and deposits upon the coal partly white flowers (consisting of zinc), and partly yellow ones (consisting of lead): it is not magnetic, either crude or roasted:
when

when exposed to the flame, in such a manner that the divided apex of the flame is reflected, it frequently appears tinged with zinc.

The second is little changed by pulverization ; it strikes fire with steel on account of the quartzose matrix ; it neither decrepitates nor smokes, and generates flowers but sparingly ; yet it sometimes tinges the flame.

The third produces an ashen brown powder ; does not decrepitate ; exposed to the apex of the flame, it exsudes small drops, and disperses flowers.

The microcosmic salt dissolves the first, and at the beginning puts on an opake whiteness ; but when nearly an equal bulk is added, it grows black. The second is never entirely taken up, for the quartzose part of the matrix remains ; when loaded, the globule grows milky. The third is dissolved with little effervescence, and the globule is obscured, is a little blue (from the copper) ; but by long fusion the tinge vanishes ; if continued too long, it is rendered opake.

It is to be observed of each of them, that during solution flashes break forth, such as are described proceeding from the metallic zinc, but smaller and less frequent.

Borax, with a small quantity of the first, grows yellow, with a larger quantity black,

and that almost without any effervescence. The second is more slowly taken up, yielding a yellowish green glass: by too much an opacity is contracted.

Mineral alkali attacks the first with vehement ebullition, producing grains of lead, although no galena appears mixed with it even by a glass. The second is also taken up with effervescence, forming an hepatic mass, which is also true of the third; but these yield no metal.

§ III. *Analysis of calcined Zinc.*

We shall now examine a variety of lapis calaminaris, which, in the manufactories where brass is prepared, is called Hungarian lapis calaminaris.

(A) 100 lb. of this stone, to which were added 165 of concentrated vitriolic acid, generated so great a degree of heat, as to raise the thermometer in a few moments from 15° to 65° , and a white smoke breaks forth, which yet could not pass through the tube of an alembic without the assistance of fire. This smoke, collected in distilled water, exhibited the same phænomena as are mentioned in the following paragraph, and therefore is of a vitriolic nature (§ IV. D).

(B) 100 parts of this mineral, well calcined, loses scarcely any of its weight; so that if it contains any aerial acid, the quantity is so small as not to be sensible on weighing;

ing; for the small observable decrement must be ascribed to the humidity. The same is also confirmed by solution in acids, for no effervescence appears in this operation.

(c) A double weight of nitrous acid was poured upon 100 of the same ore, which being evaporated to dryness, the same quantity was twice more added, and in like manner expelled by fire; this was done that the iron being calcined might remain insoluble: during this operation the vapours were somewhat red.

The mass being again put into nitrous acid, the zinc alone was dissolved by phlogisticated alkali, and a white sediment was precipitated, which, when washed and dried, weighed about 359 lb. The insoluble residuum, well elixated and dried, weighed nearly 16 lb.; this, with three times its weight of concentrated vitriolic acid, was evaporated to dryness in a sand bath; a solution was then extracted with distilled water, which yielded, by means of phlogisticated alkali, about 12 lb. of Prussian blue: the liquor remaining produced, by subsequent crystallization, a true alum, but in very small quantity.

Finally, there remained 12 lb. which eluded the force of the acids, and which was of a filiceous nature.

(D) All these being considered, there are found in 100 of this lapis calaminaris, 84 of calcined zinc, 3 of calcined iron, about 1 of pure clay, and 12 of filiceous earth.

Y 3

(E) This

(E) This analysis has also been conveniently performed in another way: first, by abstracting vitriolic acid, then elixating with water, finally precipitating by caustic volatile alkali, and dissolving. The residuum, which resists the vitriolic acid, is siliceous earth; that which refuses the volatile alkali contains a calx of iron with pure clay, which, when dissolved in vitriolic acid, may be separated by phlogisticated alkali.

(F) We shall finish by adding somewhat here concerning the calx of zinc, artificially prepared, which commonly goes by the name of flowers of zinc. These are easily and totally dissolved by acids, generally without any motion, but sometimes with a vehement effervescence. Some flowers, which had been made by Von Swab in the year 1742, were quietly dissolved after the space of thirty-seven years; whereas others, made in 1758, excited a violent effervescence like chalk, inasmuch that one would be induced to suppose at first that chalk was mixed with them; but upon examination nothing heterogeneous was found. The elastic fluid which was extricated shewed, upon examination, all the properties of aerial acid. This difference is undoubtedly occasioned by the quantity of the aerial acid surrounding the mass during calcination, and shews that the dephlogistication may be effected without the reception of that acid.

The

The flowers, which are extremely white, exposed to the action of dephlogisticated marine acid for some days in a close vessel, grow almost black, but are not (like white arsenic) resolved into an acid liquor.

§ IV. *Analysis of aerated Zinc.*

The specimen of aerated zinc first examined, was that brought from Holy-Well in England, the same which had been examined before by the blow-pipe (§ II.)—Of this

(A) 100 lb. reduced into a subtile powder, lost by calcination 34 lb. but did not betray the slightest traces of a sulphureous odour.

(B) As it dissolves in marine acid with effervescence, and without any hepatic odour, the operation was performed in a chemico-pneumatic apparatus, in order to examine the nature of this volatile vapour. 100 lb. in this way yielded only ten cubic inches of elastic fluid; but the water through which it passed, amounting to 30 inches, was found almost saturated. In order therefore to determine it more accurately, it was collected in mercury, and exhibited about 28 cubic inches, which were all absorbed by distilled water, and imparted to it all the properties communicated by aerial acid. Now 28 cubic inches of that acid, in a moderate temperature, weigh about so many assay pounds, but in calcination 34 are lost;

fix therefore remain, which doubtless are owing to water, for it appears from (D) that no aerial acid is present.

(c) The experiment was repeated in the same way, but the vitriolic acid employed instead of the marine; an equal bulk of aerial acid was produced.

(D) In order to discover whether any vestiges of marine acid remain hid in this ore, to 100 parts, reduced into a very subtile powder, were added 165 of concentrated vitriolic acid, in a small cucurbit fitted with an head, the orifice of whose tube was plunged under distilled water. No smoke or smell was perceived. The cucurbit was therefore placed in a sand bath, and fire being applied, the mixture at length sent forth a white smoke, which, passing through the water, there deposited whatever acid it contained, and the water loaded with this fume reddened paper tinged with turnsole. Some drops of a solution of nitrated silver were dropped into a small portion of this, upon which clouds arose, but these quickly vanished upon the addition of a quantity of distilled water. But as vitriolated silver is much more soluble than salited silver, a suspicion arose of the presence of vitriolic acid, which was further confirmed by the dropping in of nitrated mercury prepared without heat; for the white striæ which appeared upon this instillation, upon the further addition of a large quantity of water fell to the bottom

bottom in the form of a yellowish powder: besides, the addition of salited terra ponderosa to another portion, immediately generated a spathum ponderosum, the most certain sign of vitriolic acid. If therefore marine acid be present in some vitriform ores of zinc, this must be considered at least as accidental, and by no means necessary to their composition.

(E) Vitriolic acid takes it up almost entirely, leaving scarcely 00,1 remaining undissolved; and evaporation being continued to dryness, so as to expel the superfluous acid, the solution, on the addition of water, yields by crystallization 326 lb. of white vitriol.

(F) Phlogisticated alkali, added to a solution of this vitriol, throws down a mixed mass, white and spongy, yet containing a few particles of Prussian blue; which shews that a small quantity of iron is present. It is worthy of observation, that the blue atoms gradually become of a brownish red; whether they be suffered to remain in the liquor for some days, or whether they be separated by filtration, washed, and dried.

(G) 100 parts of vitriform zinc, with powdered charcoal, and 150 of copper, treated in the usual way, communicated to the copper an increment only of 15 lb. though in this operation a great part of the zinc always is destroyed by deflagration.

(H) Upon

(H) Upon comparing all the experiments, it plainly appears, that in 100 of this English mineral there are 28 of aerial acid (B, c), 6 of water (B), and of calcined zinc (with a very small portion of ochre scarce exceeding 1) about 65 (E, F).

(I) For the sake of comparison it must be added, that the artificial glass of zinc, arising from the distillation of this semi-metal, dissolves in acids without any effervescence; so that it also contains more zinc, and the other variety mentioned in § II. (B) is produced.

§ v. *Analysis of vitriolated Zinc.*

Zinc, in a saline state, has hitherto been but rarely found, and always united with vitriolic acid; scarcely ever pure, but united with vitriol of iron or of copper, or both together. We shall therefore first examine it in its pure state, in order to discover occasional differences the better.

(A) Vitriol of zinc yields transparent crystals, clear as water, and without any colour; they exhibit compleat quadrangular prisms, two of whose opposite sides are broader; the terminating pyramid has also four sides: in general, however, in the two opposite angles of the prism, a small defect is observed, so that the section becomes hexagonal. The native vitriol is generally stactitic, arising from the spontaneous calcination

nation of pseudo galena. The crystals rather calcine than deliquesce.

(B) By gentle calcination 100 loses about 40, which consist of water.

After a white heat of three hours, no more remained than 20 of ashen brown coloured powder; yet that metallic zinc, by calcination, is encreased at least 0,17, plainly appears, for 20 of calx are produced from little more than 17 of the metal: 100 of white vitriol therefore contains 20 of calcined zinc, 40 of vitriolic acid, and 40 of the water necessary to crystallization.

(c) In a moderate temperature 100 of the crystallized vitriol require to dissolve them 228 of distilled water. By a boiling heat much more is taken up.

(D) If to a solution of the 100 just mentioned, be added a phlogisticated alkali, whitish particles are soon separated; which, collected, washed, and dried, after compleat precipitation, yield 83 of a yellowish white powder. Now, 1 part of metallic (that is 1,17 of calcined zinc) yields to phlogisticated alkali nearly 5, therefore 83 indicate $16\frac{1}{3}$ of metallic zinc; which agrees altogether with an experiment already tried in another way (B).

(E) A solution of 100, precipitated by aerated alkali, yields a white powder, in weight 38, which is taken up by acids with an effervescence which continues till the very last particle is dissolved; therefore 20
of

of calcined zinc are able to fix 18 of aerial acid and water together. Hence we derive an illustration of what has been already said concerning its effervescence in acids (§ IV. F.). Zinc, when once calcined without aerial acid, afterwards attracts it scarcely at all, or at least very slowly.

(F) White vitriol, mixed with green, blue, or both, cannot be separated from them by crystallization.

The mixture may in some degree be judged of by the colour. The form of the crystals is spathaceous, even though the inquinament does not exceed $\frac{1}{4}$. The phlogisticated alkali betrays copper by a brownish red, and iron by blue particles, the former of which, particularly, distinctly appear on the first instillation, mixed with the white, provided the liquor be not shaken. On the addition of zinc, both the copper and iron are precipitated.

§ VI. *Analysis of the black Pseudo Galena of Dannemer.*

I have tried by various methods to discover the composition of the pseudo galena, but shall here only mention those which seemed peculiarly adapted to the purpose in each particular case.

(A) By a white heat of four hours, 25 out of 100 flew off; at the same time a strong smell of sulphur was perceived, scarcely mixed

mixed with that of arsenic, but no flame, nor were any flowers of zinc discernible; the colour of the roasted powder was like that of bricks.

This operation being finished, the quantity of volatile matter is generally estimated from the decrement of weight; but when we are examining ores by this method the quantity is made less than it ought, as metals gain weight by calcination. Lead gains about 0,12, copper 0,16, zinc 0,17, and iron 0,36. In the present case, the quantity of the metals otherwise known (if they be supposed in a perfect state) shews that by the dephlogistication the weight of the remaining mass is increased by 12. This correction therefore should not be neglected.

(B) Six hundreds of the pseudo galena being exposed to heat in a close apparatus, no elastic fluid appeared; a little sulphur was separated, and nearly 6 lb. of reguline arsenic collected in the upper part, as also about 36 of water in a tube fitted for receiving it; viz. to the extremity of the alembic tube, turned upwards, was fastened a wet bladder well emptied of air by pressure: during the operation it was a little inflated, but on cooling collapsed again; the water filled the tube; the reguline arsenic covered the upper part of the cucurbit with a black scale.

(C) As lead is found in this ore (§ 11.), the 75 parts remaining were boiled in marine acid so long as any thing was dissolved; to the

the solution, filtered, and inspissated by evaporation, was added vitriolated volatile alkali, by which a vitriol of lead was partly separated instantly, and partly by further evaporation. This vitriol yielded about 6 lb. of lead.

(D) The remaining liquor was evaporated to dryness; and, for the purpose of calcining the iron, nitrous acid was repeatedly evaporated from it, the last time even to ignition. Finally, it was dissolved in that acid; but there remained 13 of calcined iron, which is equivalent to about 9 of the metal.

(E) A solution of zinc, precipitated by phlogisticated alkali, yielded a whitish yellow sediment, weighing 223 lb. which indicate nearly 45 of metallic zinc (§ v. D).

(F) The marine acid mentioned in (B) was resisted by 4 parts, which dissolved with great difficulty in microcosmic salt, but more easily in borax, and in mineral alkali with effervescence: these properties indicate a siliceous nature.

(G) Upon a just calculation, therefore, it appears, that the 100 under examination contains 29 of sulphur, 1 of regulus of arsenic, 6 of water, 6 of lead, 9 of iron, 45 of zinc, and 4 of siliceous earth. There is no doubt but that the proportions vary a little in the various specimens: besides, in order to determine all the quantities with precision, it would be necessary to know the deficiency of phlogiston occasioned in me-

tals by their union with sulphur; a circumstance which however is yet unknown: somewhat is certainly lost, but it should appear the loss is but small.

§ VII. *Analysis of the brown Pseudo Galena of Sahlberg.*

(A) The brown pseudo galena of Sahlberg, properly roasted, loses only 0,13, of which 5 are water. The sulphureous odour is less perceptible in this than in the former analysis.

(B) Nitrous acid was repeatedly abstracted from the other 87 parts, even to ignition, and afterwards whatever that menstruum could take up was dissolved.

(C) The solution, on examination, only yielded zinc, which when precipitated by phlogisticated alkali yielded 218 lb. of sediment, and then by volatile alkali 3 parts of clay.

(D) From the remaining 31 parts, which resisted the nitrous acid, the vitriolic was abstracted to dryness; upon which it was elixated with distilled water, and 24 only remained.

(E) The solution of (D), precipitated by phlogisticated alkali, yielded 29 parts of Prussian blue, which nearly correspond to 45 of iron.

(F) The Prussian blue being separated by filtration, the liquor had an aluminous taste;

taste; and this salt also appears upon crystallization, but mixed with vitriolated vegetable alkali.

(G) The 24 parts untouched by the acids, were the reliquæ of a quartose matrix.

(H) Therefore 100 of this ore contains about 17 of sulphur, 5 of water, 44 of zinc, 5 of iron, 5 of clay, and 24 of quartz.

It is probable that in this instance the zinc is more dephlogisticated than in the others. Hence, from the unknown quantity of the difference, an error arises, perhaps of some pounds, which as yet cannot be determined.

§ VIII. *Analysis of the Pseudo Galena of Boval, which possesses a metallic Splendor.*

(A) 100 of the pseudo galena of Boval, lost by roasting 17, which by their smell seemed to be nothing but sulphur; but distillation shews that a small quantity of water is also mixed with them.

The residuum grows black on calcination.

(B) The 83 parts which remained were wetted with three times their quantity of concentrated vitriolic acid, and evaporated to dryness; then all the saline part was separated from the white mass, by boiling in distilled water, and 6 parts remained which eluded the action of the menstruum; which were with difficulty taken up by microcosmic

mic salt; more readily by borax, but very easily, and with effervescence, by mineral alkali; at the same time the last globules were brown: hence it appears that they consist of a filiceous and martial matter.

(c) In this instance the colour of the solution does not betray copper, which yet is shewn by the microcosmic salt (§ 11.); but the addition of iron soon removes all doubt. In order to determine the quantity of this metal, a polished plate of iron was boiled in the solution as long as any of it continued to be taken up. The cupreous sediment, collected, washed and dried, weighed 4 lb. The plate was found to have lost 6 lb.

(d) In the remaining liquor phlogisticated alkali precipitates at once a white and a blue sediment, which indicates the presence both of zinc and iron. In order to determine the proportions, this liquor, evaporated to dryness, was long calcined in the open fire; afterwards nitrous acid was repeatedly abstracted to dryness from the mass, that the iron, spoiled of phlogiston, might be rendered insoluble in that acid:—nor was the experiment unsuccessful, for the zinc alone was taken up, and about 19 lb. of calcined iron remained, which are equivalent to 14 parts of regulus, the weight being increased 0,36 by calcination.

(e) The solution, containing zinc precipitated by phlogisticated alkali, yields 259 parts of white sediment, washed and dried.

(F) 100 of this ore, therefore, contains 52 of zinc, 8 of iron, 4 of copper, 26 of sulphur, and 4 of water, together with 6 of a siliceous and martial matter.

(G) That the metals exist either in a state nearly reguline or but little dephlogisticated, easily appears both by the metallic splendor, and the violence and redness of the vapours with which the nitrous acid attacks them; and, finally, by the union with sulphur. The same is nearly true of the ore of Dannemer, which, although destitute of metallic splendor, exhibits the same phenomena with nitrous acid (§ IX. c); and, besides, on sublimation, it exhibits a reguline arsenic (§ VI. B). But the pseudo galena of Sahlberg seems to contain a smaller portion of phlogiston.

(H) It follows, from the analysis of pseudo galena, 1. that lime, though it be sometimes present, is not necessarily required; for the three varieties I examined did not shew the slightest trace of it, even when the acid of sugar, its nicest test, was employed; it is certain, if the sulphur was here united with zinc in the state of an earthy hepar, that a small quantity of lime would not suffice, and part at least of the hepar might be elixated by water. 2. That the presence of cobalt and silver is accidental, as also of lead and arsenic in the Dannemer pseudo galena, and of copper in that of Boval. 3. That zinc, iron, and sulphur, are always present;

present; for zinc cannot be united with sulphur, but by means of iron. When these three ingredients are fused together, an artificial pseudo galena is easily made. But it may be gathered from the water, that nature has effected the union in the humid way.

§ IX: *The Phenomena of the hepatic Smell, extricated by Acids from Pseudo Galena.*

When the vitriolic or marine acid is poured on pseudo galena; an hepatic odour is exhaled; but it may be gathered from what goes before, that no alkaline salt nor absorbent earth is present, and therefore no hepar. Hence the cause of this phenomenon may be properly enquired after. —The following experiments will serve to solve the problem.

(A) Six assay 100 of black pseudo galena from Dannemer, well pounded, were put into a glass, and the bulb of the thermometer was set in the midst of it. 300 of concentrated vitriolic acid being poured on, a few bubbles arose, and a distinct hepatic odour was perceived. In four minutes the mercury arose from 16 to 27; but in nine it began to sink. The powder was so much indurated, that it was difficult to separate the thermometer without breaking it.

(B) The experiment was repeated with 200 of smoking marine acid. A strong hepatic odour, and a violent effervescence, were
Z 2 observed;

observed; but the mercury in the thermometer remained without motion.

(c) 200 of smoking nitrous acid, diluted with an equal quantity of water, were poured on the same weight of ore, when an intumescence was perceived, and red vapours arose, without any hepatic smell. A heat of 74° took place in four minutes.

The residuum, after having been well washed with hot water, produced no hepatic smell, either with the vitriolic or marine acids.

(d) The hepatic vapour, extricated with the assistance of heat by vitriolic acid, out of a quintal, and collected in quicksilver, amounted to two cubic inches; but the marine acid produced seven from the same quantity. The red fumes arising when nitrous acid is employed were found on examination to be nothing but what is called nitrous air.

(e) One-half of a quadrant of hepatic air, collected in an inverted phial, and mixed with an equal portion of nitrous air, becomes grumous, and deposits sulphur; and the mercury in the thermometer suspended in it rose to 6° .

(f) Yet all the pseudo galenæ are not equally affected by acids: if marine acids be poured on the three above examined, that of Dannemer emits an hepatic air, with many bubbles; from that of Boval fewer bubbles rise; and from that of Sahlberg, scarce

scarce any. The two first yield a very offensive smell, even though kept in corked bottles for a number of years: the last has but a faint smell, which continues only for a few minutes: the others, boiled with acids, scarce extricate any hepatic odour.

(G) $2\frac{1}{2}$ cwt. of yellow lapis calaminaris from Hungary, treated in the same way as the pseudo galena, occasioned with vitriolic acid a degree of heat = 65° , but no hepatic smell was perceived.

(H) The same stone generated heat with nitrous and marine acid, but without any hepatic smell.

(I) Flowers of zinc occasion with acids heat, but no smell.

§ x. *Explanation of the hepatic Odour.*

From the phenomena above mentioned the origin of the hepatic odour is easily seen both analytically and synthetically. We shall first examine it *analytically*.

(A) That sulphur enters the composition cannot be doubted, as it is actually found precipitated (§ ix. E): but we are to enquire the cause which in this instance dilates the sulphur which had been so subtilely dissolved into an aeriform elastic fluid.

(B) That heat exists fixed in hepatic air, and is set at liberty by the destruction of that air, evidently appears from the ascent of the mercury (§ ix. E.) The opinion that the heat of bodies consists in a certain intestine

motion of their parts, is at present held to be totally improbable. Many circumstances tend to prove, that heat is to be attributed to a matter distinct from all others, which when disengaged occasions sensible heat in proportion to its quantity; but so long as it constitutes a primary principle of bodies, its power of heating is repressed (in the same way as the properties of an acid saturated with alkaline salt) which power, however, it again recovers, when by any means set at liberty; hence, in certain solutions, heat is generated; namely, when that principle which had been united with one of the ingredients is expelled by a stronger attraction: in others cold is produced, occasioned by the heat entering into the new compound. Since, therefore, on precipitation of sulphur from hepatic air, heat is generated, we may conclude that the matter of heat had been before fixed. This conclusion will be further confirmed hereafter (E.)

(c) It appears plainly, that the phlogiston in hepatic air forms the bond of union between the matter of heat and the sulphur; for that air cannot be decomposed, except by substances which are extremely greedy of phlogiston; concentrated nitrous acid possesses this power, even in water loaded with hepatic air; nay, nitrous air, although so much loaded with phlogiston that its acid properties are concealed, produces the

same effect (§ IX. E.) We see therefore, that upon the abstraction of phlogiston the whole composition is destroyed, so that it may justly be considered the bond of union. Sulphur, by means of heat alone, diffuses no hepatic smell.

All this is completely established by a right consideration of the principles of the pseudo galena, and its different habits with respect to acids. We now proceed to examine this subject *synthetically*.

The constituent parts of hepatic air being thus discovered by analysis, let us now examine synthetically whether these are to be found in the pseudo galena.

(D) Of sulphur we can have no doubt, as even the quantity of that has been already determined (§ VI.—VIII.)

(E) The presence of the matter of heat is equally certain, for the pseudo galena with nitrous acid excites a considerable degree of heat (§ IX. C.); and the vitriolic acid generates with it a degree of heat, though less. Thus we see the matter of heat more or less set at liberty.

(F) Besides the phlogiston of the sulphur, no small portion of that principle adheres to the metals, as has already been evinced (§ VII. G.)

All the principles therefore before discovered by analysis are present (A—C.)

(G) It may now be questioned, whether these principles are so united in the pseudo

galena as actually to constitute hepatic air, which, like the aerial acid in chalk, lies hid; or whether it be on the addition of the proper acid that they first coalesce and form an elastic fluid.

(H) In order to determine this question, the pseudo galena was subjected by itself to distillation; and the vapour extricated was collected in a pneumatic apparatus: but on examination nothing was obtained but a small portion of water, and nothing at all aerial: besides, all the different acids would expel the same quantity, if the hepatic air lay hid, like the fixed air in chalk; but we have seen, that from 1 cwt. none was obtained by nitrous acid, two cubic inches by the vitriolic, and seven by marine acid (§ IX. D); the elastic fluid therefore does not pre-exist in a perfect state.

(I) It is generated therefore during the solution: for the addition of the acid, by loosening the texture of the mass, sets the heat at liberty, together with the phlogiston of the zinc and iron; for no metal is taken up by acids, until it is dephlogisticated to a certain degree. The first effect therefore of acids upon metals is to deprive them of that portion of their phlogiston which prevents their solution, and by this privation they become soluble.

These two principles, heat and phlogiston, being set at liberty, seize the sulphur which they meet with, combine with it, and

and form an elastic fluid; but as the nitrous acid attracts and retains phlogiston with more force than the rest, with it a great heat is generated, but no hepatic air can be formed, for the principle which should connect the other two is wanting. The vitriolic acid indeed attracts phlogiston less powerfully than the nitrous, but does not yield up all that it sets at liberty to the generation of hepatic air; and this air is consequently produced only in small quantity, indeed so small that some heat remains at liberty: but the marine acid, being naturally loaded with phlogiston, does not attract any more; therefore the whole of the heat may very easily be fixed by the phlogiston extricated by this acid from the metals; hence, with this acid, there is no heat generated, but a considerable quantity of hepatic air. The calcined pseudo galena retains, indeed, the matter of heat, but loses the phlogiston and the sulphur in the fire; therefore no vestiges of hepatic air can arise here, as with the lapis calaminaris (§ IX. F, G.)

All these circumstances agree so perfectly, that no doubt can remain of the truth of the explanation; yet pseudo galena is not to be considered as the only body in nature which can produce an hepatic air and odour on the addition of acids: it is enough to mention galena, which occasionally exhibits the same phenomena; for the marine acid acts most efficaciously, but the nitrous shews not the least

least vestiges of any thing hepatic; and in this case the vitriolic acid has little effect, as it hardly attacks lead, when in a metallic state. It is also worthy of observation, that native Siberian iron, with marine acid, diffused a distinctly hepatic smell; but the examination of this would require a separate treatise.

§ XI. *Phosphoric Quality of the Pseudo Galena.*

Some varieties of pseudo galena upon friction shine in the dark; and among those the most remarkable is that which is found at Scharfenberg, in Misnia. This, when rubbed with glass, a bone, iron, or any hard substance, emits a foetid smell; and at the point of contact sends forth a flame of a gold colour, and this happens in water, nay, even in acids, and it retains this property even after a violent white heat. Some insist that this light is electric; but the electric flash is of a very different kind, being entirely extinguished by water, whereas this is made rather more splendid. Latent light is not the cause, for in solution no light is occasioned.

Supposing that light be nothing but the matter of heat, with a determined superabundance of phlogiston, these principles are not deficient in the pseudo galena; for
we

we have already seen that the matter of heat is really present (§ x. b, e), and at the same time phlogiston (§ x. c, f). The first, therefore, excited and set at liberty by friction, may easily seize the latter, and produce light.

Many varieties do not shine at all, some scarcely, and a few very remarkably; this is undoubtedly owing either to the proportion of the principles, or their closeness of connection; which last opinion is confirmed by observing that those which possess the phosphoric quality in the most eminent degree resist the three mineral acids, so that either no hepatic odour or heat arises, or at least much weaker than in the others, which indicates a firmer texture; yet all that resist the acids are not found to be phosphoric. This difficulty is solved by the analysis of the pseudo galena of Scharfenberg, the scarcity of which has as yet prevented the experiment from being sufficiently varied. The powder, exposed alone to fire in a close vessel, yields a siliceous sublimate, similar to that produced by mineral fluor and vitriolic acid. The fluor acid is therefore present, but probably united in such a manner to the metallic base, that it cannot, by fire alone, be expelled, and generate with water a siliceous earth.

Marine acid by boiling dissolves it, when well powdered, almost entirely, and produces an hepatic smell; for, exclusive of the sulphur,

phur, scarce more than 0,01 remains, which, examined by the blow-pipe, appears to be siliceous. In 100 the zinc forms nearly 64, iron 5, sulphur 20, water 6, fluor acid 4, and siliceous earth 1 ;—nothing calcareous is found.

This pseudo galena is lamellated, yellow, and semipellucid ; but, situated in a certain way with respect to the eye, it appears opaque, somewhat resembling a metal, like most of the others. The various proportions seem to indicate, that in this instance the metals are not present fully calcined. Fused with microcosmic salt by the blow-pipe, it throws out a few flashes almost like that of Sahlberg, which was mentioned among the Swedish pseudo galenæ (§ 11.), a phenomenon which can hardly be produced with calcined zinc. With nitrous acid it produces certain vapours. It is indeed true, that it excites a very small detonation ; for the first parcel thrown into nitre, well fused, occasions nothing but an effervescence ; and it is not until the fourth or fifth addition that sparks are produced, and even these are few. The Swedish pseudo galenæ, first examined, detonate on the third or fourth addition : this difficulty of detonation rather points out the closeness of connection in the inflammable principle, than a deficiency of it ; for on the same ground we might dispute the presence of sulphur, which yet is most certainly present.

DISSER.

DISSERTATION XXIII.

OF

METALLIC PRECIPITATES.

§ 1. *Design of the Work.*

THE man who first saw a metal corroded by a limpid menstruum, in such a manner that a body so extremely ponderous and so opaque should gradually and entirely disappear, and afterwards, upon the addition of a suitable precipitant to a liquor which appeared to be simple and homogenous, saw that metal separate, and again come into view;—the man, I say, who first saw this, must have been struck with astonishment and admiration. Persons accustomed to these wonderful phenomena neglect

neglect perhaps too much the accurate investigation of them, though these operations are of the highest importance, and form as it were the whole of the effective part of chemistry. The phenomena of this kind are so various and so intricate, that a single volume would be utterly insufficient for examining them all: we shall here therefore only examine such as relate to the separation of metals from acids, particularly with regard to the weight of the precipitate. Weighing is, no doubt, a mechanical operation, but yet is of singular service not only in investigating the properties of bodies, but in directing those properties to their proper uses. All effects are exactly proportioned to their causes; therefore, unless their mutual relations be examined by accurate trials, theory (of consequence the whole of natural philosophy) must be lame and imperfect.

That we may the better understand the nature of precipitations, we shall briefly examine the phenomena of metallic solutions in general.

§ II. *Examination of Metallic Solutions.*

A small piece of a metal being put into an acid, is taken up slowly or quickly, with violence, or gently, according to the various nature of the metal and the menstruum.

(A) As

(A) As to menstrua, when unassisted by heat, the nitrous acid is found the most powerful, so much so as sometimes to exceed the bounds required; and the metal dissolved is again separated, unless the violence of this acid be properly tempered: yet sometimes the nitrous acid alone has no effect, as is the case with gold and platina; but when the nitrous is united with the marine acid, the solution is readily effected.

The vitriolic acid, though very highly concentrated, yet acts more weakly. It does not attack mercury or silver, unless when boiling; and gold and platina elude its force, even though boiled to dryness.

Marine acid acts still more weakly, unless it be dephlogisticated (a); in which state it dissolves all metals compleatly.

The other acids, as the fluor acid, the acids of arsenic and borax, and all those obtained from the organized kingdom, are in general inferior in solvent virtue to the preceding.

(B) With respect to the metals, some are very easily dissolved, others not without great difficulty, and that in the same menstruum. Zinc and iron are readily dissolved in every acid; silver eludes the marine, and gold even the nitrous acid. Yet these metals, which in their natural state obstinately

(a) Nov. Act. Upsal, vol. ii.

resist solution, may be made soluble by depriving them of a proper proportion of their inflammable principle. I expressly mention a proper proportion, for experience shews, that iron, and particularly tin, are made refractory by too much dephlogistication; but nothing more plainly shews the limits of this process than manganese, which when calcined to blackness cannot be dissolved without the addition of some inflammable matter, but when reduced to whiteness dissolves in all acids (b).

(c) If we consider the manner of the solution with accuracy, we shall find that the diminution of complete metals, even to the last visible particle, is accompanied by an effervescence; that is, innumerable air-bubbles continually rise from the surface of the metals, and float to the surface of the surrounding liquor. These are the more frequent, in proportion to the quickness of the solution, and are very few, and scarcely visible, when it proceeds very slowly.

The elastic fluid, which is thus extricated from metals by nitrous acid, if collected by a proper apparatus, and examined, is found to be nothing more than what is commonly called nitrous air; but when the menstruum is concentrated it absorbs a considerable quantity of this air. By means

(b) See the Treatise on the white Ores of Iron.

of vitriolic acid inflammable air is obtained from zinc and iron, as also by means of marine acid; but from the other metals dissolved in vitriolic acid, we obtain another species of air, called *vitriolic acid air*; and by the marine acid, another similar to the former, called *muriatic air*, but both more or less mixed with inflammable air.

(D) Frequently, during the solution of a metal, heat is generated in the liquor, the intensity of which follows the compound ratio of the bulk of the mass, and the quickness of solution; therefore, when the mass is very small, and the solution proceeds very slowly, the temperature scarcely suffers any alteration.

(E) The calxes of metals, during solution, either give out no air at all, or else the aerial acid; unless when, after being evaporated to dryness, they are urged by a violent heat almost to ignition; for in this state, by means of vitriolic or nitrous acid, they give out a portion of pure air, which cannot be got by means of marine acid: according to circumstances, a vitriolic or nitrous air is also sometimes produced, and even that species which is commonly called phlogisticated air.

(F) Various metals, when dissolved, impart certain determined colours to their menstrea; such are gold, platina, copper, iron, tin, nickel, and cobalt; the rest, if properly depurated, yield no tinge. A so-

lution of silver, at first, is sometimes of a blue or green colour, although there be no copper present. The vitriolic acid grows blue with copper; the nitrous may be made either blue or green at pleasure; the marine varies according to the quantity of water with which it is diluted; manganese, when too much dephlogisticated, renders both the vitriolic and marine acids purple.

§ III. *Explanation of the above-mentioned Phenomena.*

At present no one can reasonably doubt that solution is the effect of attraction; we may therefore lay that down as a fundamental proposition, and proceed to illustrate (in the best way we are able) the more remarkable circumstances of the operation, considering it not in a general view, but merely as it regards metals.

Upon attentive consideration it readily appears, that “*no metal can be taken up by an acid, and at the same time preserve the whole quantity of phlogiston which was necessary to it in its metallic state.*” A certain proportion therefore of the principle of inflammability may be considered as an obstacle, which must be removed before solution can take place. Let us see now how this doctrine will apply to the more remarkable phenomena separately considered.

(A) Of

(A) Of all the acids the nitrous attracts phlogiston the most powerfully, and separates even from the vitriolic acid. If this be doubted, let sulphur be slowly boiled in concentrated nitrous acid, at length all its phlogiston will be found separated, and the vitriolic acid will remain deprived of its principle of inflammability. The extraordinary solvent power of this acid, therefore, is conformable to the peculiarity of its nature in this respect; for this menstruum adapts metals for solution with the greatest ease, most commonly without any assistance from external heat, which in some instances would be hurtful, by separating too much of the phlogiston. This last case is sufficiently illustrated by iron, tin, and antimony, all which may be so far deprived of phlogiston as to be very difficultly soluble in acids; it is therefore not unfrequently necessary to temper the activity of this menstruum by water.

The vitriolic acid does not act upon silver or mercury, unless when boiling; for by means of the heat the watery part of the acid is diminished, its power is thereby increased, and the connection of the inflammable principle with the metallic earth is diminished.

Marine acid, which contains phlogiston as one of its proximate principles, must necessarily have but little or no effect on those metals which retain their principle of inflammability

flammability very obstinately; but when boiling, its watery part is diminished, and it assumes the form of an aerial elastic fluid, in which state it powerfully attracts a larger proportion of phlogiston than before; but when dephlogisticated, it attracts phlogiston with prodigious avidity, readily attacking all metals, and rendering them soluble by the abstraction of their phlogiston, which it unites to itself, and resumes the ordinary form of marine acid. This acid, when dephlogisticated in aqua regis by means of the nitrous acid, dissolves gold and platina.

Upon this principle we can easily account for the inferiority of power in the other acids.

(B) As to the metals, they retain their phlogiston with very unequal degrees of force: a few of them, which are called the perfect metals, effectually resist calcination in the *via sicca*. In this operation, on the one hand, the fire, which wonderfully encreases the volatility of bodies, strenuously endeavours to expel the phlogiston, which certainly is the lightest of all material substances; on the other, the portion of pure air which occurs in the surrounding atmosphere attracts the phlogiston strongly: experience however shews, that these two forces united cannot decompose gold, platina, or silver, to any considerable degree; all the other metals yield to these forces when united, but not singly. Iron and zinc retain their inflammable principle

ciple so slightly, that any acid immediately acts upon them; but if, by dry calcination, metals be properly prepared, the menstrua will immediately take them up; nor is there need of any further privation, which, on the contrary, would be injurious, and precipitate what was before dissolved. For example, let us recollect the effect of the nitrous acid: this, added to solution of tin or antimony in marine acid, by its extraordinary violence carries off so much phlogiston that the calxes, being too much deprived of that principle, are precipitated.

(c) We are now come to the most difficult point of all, I mean the production of the various elastic fluids which resemble air. The complete discussion of this subject does not properly belong to this place; but, as some circumstances, hereafter to be mentioned, cannot properly be understood without a knowledge of the fundamental principles of this phenomenon, I think it necessary to give a brief relation of what I have been able to learn on this head, from my own experiments and those of others; some of which I apprehend to be certain, and past controversy; others (as yet only plausible) to be confirmed, corrected, or rejected by new experiments.

A great variety of different aeriform fluids have been observed; of these eight only are certainly known with respect to their com-

position; these are the fluids extricated by the vitriolic, nitrous, and marine acids, fluor acid, vinegar, alkaline salts, and hepar sulphuris.

Pure vitriolic acid, exposed to a violent heat, is indeed resolved into vapours, but vapours of such a nature, that when the heat is gone they condense again into an acid liquor of the same nature as before; but if any substance be added which is loaded with phlogiston in a separable state, by means of fire an elastic vapour is produced, which is not condensable by the most extreme cold, provided it does not come in contact with water. This is the *vitriolic acid air*, which may be totally absorbed by water; in which case the bond of union between it and the phlogiston is so weakened that this last gradually flies off, and at length common vitriolic acid is regenerated. We see, therefore, that this acid, by means of a sufficient quantity of phlogiston, may be expanded into an elastic fluid.

The nitrous acid undergoes a similar and more perfect change in a manner still more obvious:—let a small piece of silver (for example) be put into nitrous acid, and instantly innumerable bubbles arise, and float to the surface; these collected produce the *nitrous air*. The bubbles upon the surface of the metal, where the acid particles are sufficiently loaded with phlogiston, assume an elastic and highly dilated form; so
that

that they rise by their specific levity, and chase one another from the several points of the metal. The nitrous acid saturates itself with phlogiston more greedily than the vitriolic; and therefore the elastic fluid does not unite with water, and retains scarcely any vestige of an acid nature. Synthetical observations agree perfectly with analysis; for upon the access of pure air, which possesses a still greater attraction for phlogiston, the acid yielding it up immediately reassumes its original form and properties; but the nitrous air differs somewhat from the vitriolic also in this respect, that the phlogiston is not only absorbed so far as to obliterate the acid nature, but even beyond that point. This I am convinced of by many experiments, one of which will be sufficient, namely, the decomposition (c) of hepatic air by means of nitrous air.

The marine acid exhibits different phenomena: this acid contains phlogiston, and by its means can be resolved into an elastic fluid called *muriatic air*, which is permanent so long as it is kept from the contact of water; but, like the vitriolic, upon the access of water it reassumes the form of marine acid. As this acid naturally contains phlogiston, there is no necessity for an addition: in the mean time this, in the same manner as nitrous air, when in its ex-

(c) See Treatise on the Ores of Zinc, § ix. E.

panded state, attracts a still larger proportion of phlogiston, and that with wonderful avidity.

When the natural quantity of phlogiston is diminished the marine acid yields another elastic fluid of a reddish brown colour, possessing the peculiar odour of warm aqua regia. This does not unite with water, or but in an exceeding small quantity; and, upon the addition of a due quantity of phlogiston, may be again reduced to marine acid. The experiments made on the black calx of manganese and on white arsenic (*d*), which I have often repeated and carefully weighed, I consider as indubitable evidences of this connection. Whether the marine acid can by any other than these two methods be dephlogisticated, I am as yet ignorant.

The fluor acid abounds with phlogiston, and therefore may, without any adventitious matter, be reduced to an elastic fluid. This air is easily distinguished from all others, as when hot it corrodes glass.

Vinegar also naturally contains phlogiston; and for that reason, when well dephlegmated, can produce an elastic vapour, which is called *acetous air*.

All these elastic fluids seem to be nothing more than the acids themselves, expanded by phlogiston. Perhaps the matter of heat also enters into their composition.

(*d*) Nov. Act. Upsal, vol. ii.

This is also the case with caustic volatile alkali, which yields the *alkaline air*.

Finally, among those elastic fluids, the composition of which we are acquainted with, we may place the *hepatic air*, in which we have demonstrated sulphur (e) united with the matter of heat, by the intervention of phlogiston.

The origin of the other elastic fluids is as yet so involved in darkness, that we can scarcely establish any thing certain with regard to them: these are of four kinds; and, in conformity with the received opinion concerning their properties, are called *fixed air*, *phlogisticated air*, *dephlogisticated air*, and *inflammable air*.

Of the first I think it is evidently demonstrated to be of a peculiar nature, and always acid. Dr. Priestley considers it only as a modification of nitrous acid; nay, he urges that the vitriolic and nitrous acids are no more than varieties of the same substance. This point I will not absolutely deny; but the foundation on which these assertions rest seems to me to be very insufficient. Thus, in the preparation of ether by vitriolic or nitrous acid, he obtained a considerable quantity of fixed air, which he affirms to have been generated during the operation; but we must observe, that a large proportion of spirit of wine enters into this

(e) Treatise on the Ores of Zinc, § ix. x.

preparation.

preparation. Now we find that fixed air abounds almost every where throughout all organized bodies; why then should spirit of wine, which owes its origin to vegetables, be supposed entirely void of it? As this is very volatile, it is only in a close vessel that it remains entire, and eludes the force of fire; but when hot, it gives off the fixed air: besides, by the addition of the stronger acid, its texture is broken, and the subtil acid, which before was latent, now breaks forth. Add to this, that, whether vitriolic, nitrous, or marine acid, or even vinegar, be used in the preparation of ether, aerial acid is produced: either then the aerial acid is common to all the acids (which is by no means confirmed) or it is derived from the decomposition of the spirit of wine; otherwise I acknowledge, that the conjecture of fixed air originating from nitrous acid, does not appear improbable; of which we shall say more hereafter.

That species of air, which is indispensably necessary for the support of flame, and for animal respiration, is generally called *dephlogisticated*. This air, united with a certain quantity of phlogiston, constitutes the matter of heat, as Mr. Scheele has demonstrated by a long train of experiments, the chief of which I have repeated with the same success. Setting this down as a principle, let us see what alterations such air is liable to. The purest air of this kind which

can be got, cannot be rendered unfit for the support of inflammation or respiration, either by flame, by nitrous air, by electrical sparks, or any other of those operations by which we certainly know phlogiston to be set at liberty; yet it contracts in dimension, and is at length entirely consumed, and that in such a manner that, united with the phlogiston, it forms the matter of heat, and, being utterly incoercible, pervades all manner of vessels. A very elegant appearance may be produced by this air; for if a piece of wood, or a candle newly extinguished, be put into a bottle containing it, provided the smallest particle remains ignited, a flame is instantly kindled with a bright coruscation, and as it were explosion: this flame is diffuse and decrepitates, and the eye can scarcely bear its splendor. When this experiment is performed in an inverted vessel, the orifice of which is kept beneath mercury, it is evidently seen that almost the whole of the air disappears; the remainder amounts to $\frac{1}{8}$, $\frac{1}{10}$, nay sometimes scarcely forms $\frac{1}{20}$ of the original bulk; and this residuum consists partly of aerial acid, and partly of air unfit for sustaining flame, or being subservient to respiration, which had been originally mixed with the pure air.

The same thing takes place on the admixture of dephlogisticated and nitrous air; sometimes

sometimes scarcely any remains, sometimes $\frac{1}{10}$ of the bulk, but in general much more. The variations in the quantity of the residuum are sufficient to shew the different degrees of dephlogistication, or (which is the same) the different degrees of purity of the air. This purity may be accounted for in three different ways: for either all its particles may be of the same nature with the whole; or a certain number of exceeding pure particles may be mixed with a determined quantity of such as are very impure; or, finally, the different particles, being each endowed with their own peculiar degree of goodness, compose a mass of an intermediate nature. Each of these cases may occasionally take place; but in my apprehension the last seems to be more conformable to the usual order of nature. With respect to the explanation of the phenomena, they all apply equally; but as the second appears to be the most simple, I chuse that. Let us now suppose the perfect nitrous air (which, upon the loss of phlogiston, is all resolved into nitrous acid) mixed to the point of saturation with dephlogisticated air, then all the elastic fluid, which had been confined by the glass, disappears, by generating heat and penetrating the vessel. This takes place if the dephlogisticated air be perfectly pure; if not, the residuum will determine the degree of its impurity. Upon this

this principle the best common aerial air is said to contain of dephlogisticated air $\frac{1}{4}$, and the worst $\frac{1}{2}$.

It is probable that good may be converted into noxious air; this must be owing either to the abstraction of something from the mass, or the addition of some heterogeneous matter to it. The ablest philosophers have, by unanimous consent, determined the latter to be the case, and consider phlogiston as the cause of this corruption.—However, let us for a minute wave these opinions, how respectable soever, and candidly enquire into the truth of the fact, at the same time begging pardon for the boldness of our attempt.

Let us examine those processes by which phlogistication is performed: let us suppose a lighted candle set cautiously in air of absolute goodness; we shall see an exceeding vivid flame, and the candle will be consumed with extraordinary swiftness, until a small portion of air remains, which exhibits the properties of aerial acid, proceeding doubtless from the tallow, into the composition of which that acid enters in great quantity. The phlogiston, being set at liberty by the combustion, is seized by the pure air, is converted into heat, and penetrates the vessels; and hence the diminution of bulk which is observed. If at first there had been more or less of air unfit for sustaining flame, that air will be in the end left

left behind entirely unchanged, together with the aerial acid; but in this case the diminution of bulk will be less.

We have already explained the mode of operation of the nitrous air.

Let a mixture of tin, lead, and bismuth, which melts by the heat of boiling water, be fused in a close glass vessel, the air which is included will be diminished in proportion to its goodness; and if this be absolutely pure, a proportional quantity of the metal will be entirely calcined, and the whole of the elastic fluid will disappear.

Electrical sparks are small flames, which indicate the extrication of phlogiston, and at the same time generate heat.

All these phenomena concur in shewing that pure air acquires, by phlogistication, so great a degree of subtlety, that it cannot be confined in glass vessels, nor be any longer inspired; but no noxious air is produced. Now, if a similar phlogistication took place on respiration, a similar diminution of bulk would also be observed, which is contrary to experiments the most accurate. Mice, when included in air confined by mercury, and suffered to die there, do not occasion, in general, a diminution of air equal to $\frac{1}{10}$, a loss which is doubtless owing to the small portion of air expelled by the heat of the animal at its first introduction. A very different operation seems therefore to be performed in the process of respiration, from that

that which is carried on during deflagration; perhaps the air rather conveys phlogiston to the lungs than takes it away. From whence does a pine, growing in the dryest sand, receive its oily matter, is it not from the air? Such animals as by manducation mix a large quantity of air with their food, are observed to grow fat in an extraordinary degree. But we shall wave those arguments drawn from analogy, and proceed to such as are more direct:—the air in which flame is extinguished, can be breathed almost as long as aerial air; nevertheless, during deflagration, phlogiston is copiously evolved, and by it the pure air is fitted for escaping through the vessels, but is not vitiated, which it always is by respiration. Fresh blood, when agitated in pure air, does not diminish its bulk, but renders it unfit for supporting flame. But if the discharge of phlogiston from the lungs was so indispensably necessary as the moderns assert, undoubtedly inflammable air would be the most noxious of all; nevertheless, the celebrated Mr. Scheele had courage to make the experiment, and to inspire air, extricated from iron by vitriolic acid, no less than 30 successive times. After this, its bulk was found the same as before; and its inflammability not only destroyed, but its nature so changed that it extinguished flame. I have myself repeated this remarkable experiment

periment with the same success, except that I was not able to inspire above 20 times.

Hence it appears at least, that phlogiston may be absorbed by the lungs, without any considerable danger. I acknowledge, that small animals, when inclosed in this kind of air, soon perish; but this does not, in my judgment, at all tend to shew, that the inflammable principle, in more simple combinations, cannot be innocent, or even salutary and necessary, to the animal œconomy. When we consider the prodigious quantity of this subtile principle, which is found in all organized bodies, the powerful effects which the proportion of its quantity produces in the formation of different substances, we shall soon see the necessity of continually repairing the loss of phlogiston which the blood suffers during circulation from the several secretions. Let the sagacious observers of nature examine carefully this problem; let them devise and execute suitable experiments, and I trust that this material point will soon be determined. In the mean time, since all organized bodies are incapable of flourishing, or even of existing, without good air, we must take leave to call this air *good*, or rather *pure*, until its dephlogisticated state is evinced by uncontrovertible arguments; and to call that air *vitiated* which is usually called *phlogisticated*, as it labours perhaps rather under

under a deficiency than a superabundance of phlogiston.

I shall here briefly explain a theory of aeriform substances, some circumstances of which I hinted in an oration before the Royal Academy of Sciences, in 1777. Some of these circumstances have since appeared to me established beyond doubt, and others of them only probable, but yet to be such as agreed well together, and are at least worthy of a more accurate examination. Whether the consequence of this examination be to establish or to overthrow them, natural philosophy will be enriched, and I will not spare them myself, if by new experiments I shall discover them to be false. In the mean time I hope that a cursory account of them will give occasion to decisive experiments.

The celebrated Dr. Priestley has shewn, by a multitude of experiments, that dephlogisticated air may be extricated from almost all bodies, by means of nitrous acid. He has also shewn, that this air is found occasionally more or less mixed, sometimes with aerial acid, sometimes with nitrous air, sometimes with that elastic fluid which is called phlogisticated air, sometimes with all of them together, yet so disposed that they generally exhibit themselves in various order; so that from the same mixture, exposed to fire in different vessels, sometimes one of these fluids will appear first, sometimes in-

intermediate; and sometimes last. He has shewn that nitrous acid is very greedy of phlogiston; and that it is wonderfully diversified by the variety of quantity and connection of this principle. I suppose it is well known that a large proportion of phlogiston in a body renders it in general immiscible with water, &c.

May not therefore the nitrous acid, by a certain quantity of phlogiston, be converted into aerial acid—the phlogiston imparting to it elasticity and levity, weakening its acidity, increasing its attraction for absorbent earths, and changing its former properties, or creating new?

May not its acidity be so far repressed by a still greater quantity of phlogiston, that it will elude our examination, refuse to unite with water, be neither easily deprived of its phlogiston, nor any further loaded with it; being unfit for respiration by its obstinate retention of phlogiston, and for the sustaining of flame by its being no longer able to take up more—thus generating that species of air which is called phlogisticated?

May it not, by an abundant quantity of phlogiston, be perfectly mitigated, and so become useful both to flame and respiration? Thence on the one hand, by any further increase of the inflammable principle, it becomes so subtilized as to generate heat, and thus sustains fire and flame, in which state it pervades all vessels; and on the other hand, by
any

any further diminution of that principle, or (if we may use the expression) a determinate calcination, returning occasionally to the state of phlogisticated air or aerial acid. Animals provided with lungs are less able to dephlogistate this air than those which breathe through spiracula, or than vegetables; the former converting it into phlogisticated air, the latter (f) into aerial acid. The experiments which have hitherto been instituted in another way shew a very different effect of vegetation upon air; but if I am not mistaken the cause of the difference depends upon the diversity of circumstances. We know that vegetables languish, grow transparent, and lose their colour in the dark; but when thus vitiated are speedily restored by the rays of the sun. Light consists of the matter of heat, with an excess of phlogiston; this excess is first absorbed, and afterwards by degrees, though with more difficulty, the phlogiston itself, which constitutes the matter of heat, is separated; for no vegetation can proceed without heat: and by this process the other principle, the pure air, is set at liberty. Therefore, according to the inequality in the degrees of heat, according to the different position of the vegetables with respect to light, according to their different power in

(f) Mr. Scheele found that good air was gradually converted into aerial acid by insects or vegetables included in it.

decomposing light and heat, dissimilar effects must necessarily take place.—Even water itself, which appears so simple and homogeneous a substance, frequently contains invisible organized bodies, which, when operated upon by the sun's light, by their vegetation produce the same decomposition, and generate pure air.

If the varieties of noxious air can be rendered wholesome by agitation in water (which I confess I have not yet examined with due accuracy) according to our hypothesis all the varieties, except inflammable air, should be loaded with phlogiston during the operation. It is known that water always contains a portion of pure air (*g*); and daily experience shews, that air dispersed through water may, by continued agitation, be again collected, especially with the help of a little heat. Do not the emendations of air depend upon this? Water deprived by boiling of its air, spontaneously recovers it when exposed to the open air: but water is not fluid without the assistance of heat, and to that end it requires a degree equal to 72° (*b*). I can scarcely believe that the matter of heat undergoes any decomposition during the agitation; but if that should so happen, an air being present which wants phlogiston, a double source of pure air will occur; the one by its superabundant phlo-

(*g*) Vol. i. p. 111.

(*b*) Vol. i. p. 286.

giston correcting the noxious air, the other, by the extrication of phlogiston, setting free the pure air which had before entered into the composition of the matter of heat.

But it is not yet sufficiently clear what rank in this order is to be assigned to the *nitrous* air: it abounds with a larger quantity of phlogiston perhaps than the aerial acid, but more weakly united, on account of the moisture which the celebrated Fontana has shewn to enter its composition. Here too we are at a loss for the reason why pure air, already loaded with phlogiston, is yet able to despoil the nitrous acid of that principle.

Inflammable air is undoubtedly charged with abundance of the principle of inflammability; but in other respects its composition is very obscure. On the one hand it cannot exist in a perfect state in bodies before its separation, as, if that was the case, it could be extricated even by nitrous acid; nor on the other, does it seem to require the admixture of any particular acid; for it is extricated from iron equally by the vitriolic and the marine, and even by any acid, except that of arsenic, and, what is most of all to the purpose, without the assistance of any acid menstruum whatever, but merely by a proper degree of heat. It is reduced by respiration to a vitiated air. If therefore the above theory be agreeable to truth, the principle of it ought to be found in the nitrous

acid; but as pure air, on the access of a greater quantity of phlogiston, constitutes the matter of heat; and that which is called inflammable air seems to exceed the pure in quantity of phlogiston, yet does not thereby acquire subtlety enough to penetrate glass; there exists perhaps in this case some peculiar connection: for we cannot easily conceive that the bare increase of phlogiston can render the texture of its parts too gross to pass the pores of the glass: we must however confess that sulphur, which is perhaps more loaded with phlogiston, is much denser than vitriolic acid. Yet, although inflammable air dissolves somewhat of the metal, carries it up, and after deposits it in water, we cannot properly conclude that the metal is necessary to its composition: in like manner other heterogeneous matters may be mixed by solution with the other aeriform fluids, and afterwards removed without injuring the properties of the fluids.

Nature proceeds by insensible gradations; but it is not in our power to follow her closely, being only capable of distinguishing the more remarkable steps. There is no doubt but other elastic fluids form intermedia between those that we are acquainted with; of this we are the more confident, as we know for certain that pure air, nitrous air, and inflammable air, are not always procured of the same degree of virtue and efficacy.

If

If this theory, gathered from such phenomena as are at present known, be true, it will not be difficult to understand the generation of nitre upon the surface of the earth; the inimical nature of aerial acid, with regard to respiration, above all other noxious fluids, a property by which it is capable, when taken into the lungs, of destroying as it were the original stamina of the animal machine; and many other circumstances hitherto involved in impenetrable darkness.

(D) As to the heat generated during the solution of metals, it is owing to the matter of heat which had been fixed in the metals, and is now set at liberty by the acid menstrua. All metals are eliquated by fire, so that we cannot determine whether this depends upon the fire used in fusion, or whether it belongs to metals themselves. Many bodies retain a considerable quantity of heat fixed, although they have never been exposed to the fire, as we have already shewn in the instance of lapis calaminaris (i).

(E) The calxes of metals are deficient in that quantity of phlogiston which is necessary to their metallic state, but yet are not entirely without it; therefore in their solution scarce any elastic fluids are generated, unless the fire be continued after exsiccation; such as contain aerial acid discharge it imme-

(i) Treatise on the Ores of Zinc, § IX. H.

diately in the same form as they had received it. It is remarkable, that Dr. Priestley mentions a calx of lead which, with the acid of phosphorus, produced an inflammable air. By means of the nitrous acid, and evaporation to dryness, a pure air is produced, partly by the decomposition of the matter of heat, and partly by the phlogistication of the nitrous air; for metallic calxes, and several other earthy matters, attract the nitrous acid, and fix it to a certain degree, so that it can be loaded with the phlogiston of the heat; during which operation the pure air, which is the other principle of heat, is set at liberty, and at length a like air is generated from the nitrous air. Pure nitre, urged by fire, illustrates this process very well. If nitre be kept red hot upon a tile for half an hour, and upon cooling vinegar be added, or even a weaker acid, immediately the phlogisticated nitrous acid is discovered by its smell; but from whence can this phlogistication be deduced, only from the heat passing through? Besides, by a long continued fire, all the acid is expelled; but a very small quantity of it may be collected in a recipient adapted for the purpose; and in the mean time, by means of a pneumatic apparatus, air of different degrees of goodness may be had in great plenty.—Does not this manifestly indicate successive changes taking place in the acid?

Some-

Sometimes a small portion of vitriolic air is had, by means of a proper degree of fire, from vitriolic acid, but a far greater quantity of pure air, occasioned by the decomposition of the heat.

(F) The solution made by the menstrua above mentioned contains a metallic calx intimately united with the acid; but the quantity of phlogiston remaining varies, according to the difference of the menstrua, and of the temperature. The operation being performed, either with or without an intense heat, frequently occasions a notable difference, as we have already observed in the instance of (k) nitrated mercury. That calcination is effected more gently by the marine than by the nitrous acid, will easily appear on pouring concentrated nitrous acid on tin or antimony; the difference is not so visible in the other metals, if it actually does take place.

As the necessity of this calcination, during the solution of metals, has been thought by some modern chemists not only doubtful but even false, let us here consider separately, but briefly, the case of the perfect metals, which they insist ought to be excepted, as they do not yield to the most intense fire. Let us therefore observe, 1st, that during their solution nitrous air is always generated, and of a very perfect kind; this

cannot arise without phlogiston, but in this case there is nothing present which can yield phlogiston, except the metals: therefore, 2d, the metals, when precipitated from the menstrua by fixed alkalis, both with respect to their external appearance and internal properties, appear to be calcined; v. g. the precipitate of gold rejects mercury, is dissolved in marine acid, and other simple menstrua, and that without the production of any elastic fluid. 3d, Glass may be stained by these metals; but no metal in its complete form can be taken up by glass, much less serve to stain it.

The vulgar objection arises from hence, that the calxes of the perfect metals may be reduced solely by means of a sufficient degree of fire, without the addition of charcoal; but this depends upon the great force with which these calxes attract phlogiston, so that they are able to decompose the matter of heat, and to take away and retain as much of that principle as is sufficient to give them the metallic form; and it is for this reason that they resist the effect of fire so obstinately, when in their metallic state; for when any phlogiston is taken away, it is instantly replaced. The calxes even of the imperfect metals attack phlogiston, but are not able to retain a sufficient quantity. Mercury is a sort of intermediate substance, as it may, like the imperfect metals, be calcined by fire alone, though with much difficulty,

faculty, and yet, like the perfect, it can from heat alone receive phlogiston to saturation.

The following has been proposed to me as an inextricable dilemma: "*Silver cannot amalgamate with mercury, except when in its metallic state, yet both salited and nitrated silver are taken up by mercury; it is therefore not calcined by the acids, but adheres to them in its metallic form.*" We shall not need any assistance from the higher chemistry, in order to solve this. It is well known that the calx of copper, dissolved in vitriolic acid, is precipitated in its metallic form on the addition of iron, and that by means of a double elective attraction; for the iron dissolving in the acid would form an inflammable air by its phlogiston, were not the copper present, which takes it up, and thereby becomes insoluble so long as it retains it: but from the table of elective attractions it appears that mercury possesses a stronger attraction for acids than silver does; if therefore salited or nitrated silver be triturated with mercury, the silver must be precipitated in a metallic, and the mercury calcined be dissolved. This also takes place, provided there be moisture sufficient to suffer the elective attractions to operate; the superabundant mercury greedily takes up the comminuted silver precipitate, and the arbores Dianæ are nothing more than such an amalgam crystallized. Upon this

head

head we shall say more (§ iv.) ; the fundamental objection is therefore, I hope, removed. But although the acids cannot take up any metal, while it retains its full proportion of phlogiston, yet various metallic salts are able to effect that solution ; thus nitrated or salited mercury boiled in water, together with the crude metal, can take up a certain proportion of it, without dephlogistication ; and the latter of these two salts by this method, even in the *via sicca*, becomes a *mercurius dulcis*, which contains at the same time a crude and a (1) calcined mercury.

Perfect solutions should in general be transparent, and some are also distinguished by a peculiar colour, namely, that colour which is proper to the calx, only rendered more vivid by the moisture. Thus solutions of gold and platina are yellow, those of copper blue or green, those of nickel of a bright green, those of cobalt are red, although the calx is black ; we may observe that even this red colour may be heightened to blackness ; iron, moderately calcined, is green, but this rarely continues upon further dephlogistication. The white calxes of silver, lead, tin, bismuth, arsenic, zinc, antimony, and manganese, are dissolved without colour ; but solutions of the lead, tin, and antimony, are somewhat yellow, unless suffi-

(1) *Acta Stockholm*, 1778.

ciently diluted. To this rule mercury forms a singular exception, for the orange-coloured calx of this metal is taken up by menstrua without colour.

That phlogiston is the chief cause of colour, appears also from hence, the black calx of manganese tinges vitriolic acid with a red colour, but on the addition of sugar the tinge is entirely (*m*) destroyed. Nitrous acid is rendered blue by copper, but when the metal is added in considerable quantity, it becomes of a very deep green; the marine acid, which dephlogisticates the copper less, is yet made green, but by dephlegmation may be so condensed as to appear brown. I have sometimes seen a solution of silver green, although there was not present the smallest particle of copper. This depends upon the absorption of nitrous air; for let smoking nitrous acid be diluted, on the addition of a certain quantity of water it will be of a deep green, by a greater blue, and upon a still greater, becomes limpid; by means of the water the nitrous air is extended to a greater space, and this attenuation, gradually increased, varies the colours. From what has been said it readily appears, why nitrous acid is made green by a large quantity of copper.

Metals dephlogisticated by acid solvents powerfully attract phlogiston; nay, nitrated

(*m*) Of the white Ores of Iron, § VII.

silver

silver and mercury, and salited antimony, corrode animal substances, in order to extract it. This metallic causticity, which is only to be moderated by phlogiston, ought to be carefully distinguished from the acid causticity, which is repressed by alkalis, and the alkaline, which is mitigated by acids. According to the quantity of phlogiston present, colours vary; and some experiments shew, that by a sufficient quantity all colour is entirely destroyed, somewhat in the same way as a white light is generated by the union of the seven primitive colours—but of this hereafter.

§ IV. *Different Species of Precipitations.*

Various are the methods by which dissolved metals may be separated from their menstrua; and the appearance and nature of those precipitates are occasionally varied in this operation in a very singular manner.—We shall mention some of the most remarkable.

(A) All metals may be precipitated by alkaline salts, which by their superior power of attraction separate them from their menstrua; but the differences of these alkalis, with respect to their nature and preparation, impresses the precipitate with different characters.

With

With the caustic fixed alkali, the calxes fall almost entirely pure, but loaded with water, and the matter of heat which is expelled from the alkalis by the acid. The weight is found to be encreased by the water, and perhaps by the matter of heat; but yet less than by the aerial acid.

With the aerated fixed alkali, by means of a double decomposition, the aerial acid unites to most calxes. We have already observed, that the vegetable alkali, completely aerated, precipitates a white calx from salited mercury, but that the mineral alkali does not possess that (n) property.

The volatile alkali, which naturally contains phlogiston, sometimes phlogisticates the precipitates: it throws down a black or white precipitate of mercury; nay, makes the orange-coloured calx white, the reason of which phenomenon we shall soon (o) see. Gold receives from this precipitant its fulminating quality, as before (p) explained.

The alkali, which is commonly called phlogisticated, generally precipitates metals with an increase of weight, as Mr. Macquer first demonstrated.

(B) Frequently the acids occasion precipitates, and that for different reasons.

By means of elective attraction, silver, mercury, and lead, are taken from the ni-

(n) Vol. i. p. 70.

(o) Vol. i. p. 132.

(p) Of the fulminating Calx of Gold.

trous acid, by the addition of the marine or vitriolic. These acids form with the metals new compounds, which are difficult of solution in water, they are therefore precipitated in greater or lesser quantity, according to circumstances.

By too much dephlogistication the nitrous acid can decompose salited tin and antimony: for when these calxes are too much calcined they reject menstrua.

(c) Alkalis, saturated with acids, which are called neutral salts, sometimes disturb metallic solutions.

By means of a double elective attraction all those which contain vitriolic or marine acid decompose solutions of silver, mercury, or lead, in marine acid, and precipitate the metals.

By forming a triple combination, the vegetable, as well as volatile alkali, although saturated with vitriolic, nitrous, or marine acid, precipitate platina from aqua regia. If the mineral alkali forms the base, the neutral salt has no power of this sort; — these phenomena are more accurately considered elsewhere.

(d) Some metallic salts can decompose others, and precipitate their bases. This may happen when the acid is different in the two salts, or, what is more singular, even though it be the same.

Solution of gold gives us an example of each

each of these two cases (*q*). This, as is well known, is precipitated by martial vitriol, although the reason, so far as I know, has not been yet explained; but upon examining the precipitate carefully it will be easily understood: for this, when washed and dried, not only shews many resplendent gold-coloured particles, but also unites with mercury by trituration, dissolves in aqua regia, but not in marine acid alone, together with other circumstances which evince a complete resuscitation of the gold. Crystallizable martial vitriol contains phlogiston, but very loosely adhering (*r*), so that the calx of the gold may very easily take it away to supply the loss it had sustained during the solution. That this is the true foundation of the process, appears also from this, that the weight of the dissolved gold is precisely recovered: it is also proved from this circumstance, that dephlogisticated vitriol will not precipitate gold. It may reasonably be enquired why the surrounding aqua regia leaves such a precipitate untouched. The reason is, that the menstruum is diluted and weakened by the quantity of water; for upon boiling it gently, so as to expel the water, the menstruum recovers its solvent power, and takes up the precipitate.—We come now to the origin of the purple precipitate.

(*q*) Treatise on Platina.

(*r*) Vol. I. p. 137, 387, 392.

That a solution of gold in aqua regia should be precipitated by a solution of tin, the same menstruum, is of more difficult explanation: — in this case, it is the same menstruum that holds the two metals dissolved; what then is the cause of the change? At first I imagined that the tin had attracted a superabundance of the acid, and taken it from the gold, which being therefore destitute of the proper quantity must necessarily fall to the bottom: but upon employing a solution containing superabundant aqua regia, the same precipitate was occasioned. The cause is therefore not to be sought in the menstruum: let us examine the precipitate itself, and perhaps the knowledge of its properties will unfold the mystery. Its external appearance shews nothing like the metallic splendor, but altogether resembles a calx: it is easily found by its weight that it cannot consist entirely of gold; and in fact chemical examination discovers a considerable quantity of tin. It cannot be dissolved by the marine acid alone, but, upon the addition of a little nitrous acid, is easily taken up: triturated with mercury, it scarcely unites with it. These properties seem to indicate that the gold has so far received phlogiston as to resist the marine acid, unless aided by the nitrous; but its earthy appearance, and its habits with respect to mercury, evince that it is not in its complete metallic form.

May not therefore the following explanation be conformable to truth?—The solution of tin necessary for this operation must retain as much phlogiston as it possibly can, consistent with solubility. This is dropped into a solution of gold very much diluted, by which means the remaining phlogiston of the tin is more loosened, and is more easily attracted by the gold calx, which is thereby brought to a state approximating to completion, so that it can no longer be retained by the menstruum; and the same happens to the tin, by means of the dephlogistication: they must both therefore of consequence fall to the bottom, mixed intimately together. It is probable that in this case, it is the tin which prevents the union with mercury.

(E) Besides, the metals precipitate one another after a certain order. This order is found to be the same in all acid menstrea, and is mentioned in another place. This precipitation is effected by a double elective attraction (s); for the metal which is to be precipitated, exists in the solution in a calcined state; but being reduced by the phlogiston of the precipitant falls to the bottom, while at the same time the precipitant being calcined becomes soluble: but if the precipitant has been so calcined, that a part of it being insoluble is mixed with the precipitate,

(s) Treatise on Elective Attractions.

the metallic splendor is wanting, and it puts on an earthy appearance. A pure precipitate is of the same weight as the metal had been before the solution. The mixed precipitates are less frequently met with, yet gold precipitated by tin exhibits one of that sort.

But many anomalous circumstances occur in this matter, depending, no doubt, upon accident. The order is indeed constant, and never inverted: zinc prevails over iron; iron over lead; lead over tin; tin over copper; copper over silver; silver over mercury, &c.: yet it sometimes happens that a metal, which, according to the general rule, precipitates another, in its metallic state, from one menstua, precipitates it from another in the form of a calx; and from a third, not at all. Some examples will illustrate this:—zinc precipitates iron from marine acid in its metallic state, but from the nitrous only in the form of a calx. Perhaps the phlogiston of the zinc is not sufficient to reduce the iron, which in the latter case has been much more dephlogisticated; yet the particles of iron, although they were at first metallized, may be again calcined in a menstruum which is very greedy of phlogiston. Tin, precipitated from marine acid by lead, appears in a complete form; but is not thrown down from nitrous acid; and from vinegar is precipitated in form of a calx, even by iron and zinc: lead lets fall nothing from

from vinegar upon the addition of iron. These and other anomalies will be expressly examined in the doctrine of attractions: it will be sufficient here to mention that a small excess of acid is necessary; and that without it no precipitation begins (t): but a great superabundance prevents that operation, by again dissolving the precipitate; besides, the weights of the precipitates and the dissolved precipitants do not correspond.

§ v. *Colours of metallic Precipitates.*

Before we consider the weights of the different metals, we shall slightly touch upon the precipitates. I employed the mineral alkali, as the degree of saturation of it with aerial acid is more constant. When I had occasion for a caustic alkali, I prepared it by a small quantity of burned lime, in a close bottle: the goodness of it was proved by its occasioning no precipitation in lime-water. The preparation of phlogisticated alkali is described in another place (u).

(A) Gold dissolved in aqua regia is precipitated by caustic mineral alkali, almost black; by the aerated, yellow; as also by the phlogisticated, unless some iron be present, which frequently happens. As the whole of the gold is scarcely ever preci-

(t) This was first observed by the celebrated Gahn.

(u) Treatise on the humid Art of Assaying, § II.

pitated, I cannot pretend to ascertain the weights.

(B) Neither the caustic nor aerated mineral alkali precipitate one half of platina, dissolved in aqua regia; the precipitate is of an orange colour, which on drying changes to a brown. An over proportion of alkali re-dissolves the precipitate with a more obscure tinge; nay, the precipitation is so imperfect, that alkali saturated with acid seems to dissolve it. The phlogisticated alkali does not precipitate the depurated solution, nor even make it turbid; but heightens the colour in the same manner as the excess of alkali does.

(C) Silver dissolved in nitrous acid is precipitated white by aerated mineral alkali; by the caustic brown; and by the phlogisticated alkali of an obscure yellow; by the nitrous as well as the marine acid, white; but the former precipitate consists of more distinct particles, which grow black more slowly in the light of the sun.

(D) Salited mercury is precipitated red, or rather ferruginous, by aerated alkali; by the caustic more yellowish, or orange. Nitrated mercury, prepared without heat, yields a ferruginous precipitate with mineral alkali; a black with caustic: when prepared with heat, it yields to caustic alkali an orange, or reddish yellow precipitate: by phlogisticated alkali it is precipitated from all acids, white; which, when dried, becomes

of a brownish yellow. Salited mercury is very sparingly precipitated by this alkali. The precipitate occasioned by phlogisticated alkali is again dissolved if too much alkali be used.

We have before shewn that a white precipitate may be obtained by aerated vegetable alkali, and have explained the cause.

Corrosive sublimate must be very cautiously precipitated by caustic, as well as aerated fixed alkali; for the part separated may again be dissolved by a large quantity of water. If too much alkali be used, a new compound arises of a peculiar nature.

(E) Nitrated lead is thrown down white by aerated, caustic, or phlogisticated alkali. If too much alkali be used, the last precipitate is dissolved with a brownish yellow colour. Vitriolated and salited lead is precipitated white.

(F) Nitrated copper, which solution is blue, is precipitated of a bright green by aerated fixed alkali; by the caustic, of a greyish brown, which grows reddish by age. By phlogisticated alkali, copper is precipitated of a greenish colour, which afterwards grows of a brownish red, and upon exsiccation almost black. The aerial acid readily takes up a small portion of copper during the precipitation, which is again deposited by the heat of boiling.

(G) Iron is precipitated green by the aerated fixed alkali, from vitriolic and marine acid; this precipitate becomes of a

brownish yellow, especially on exsiccation: with the caustic alkali it approaches more to black: in the precipitation some part is held in solution by the aerial acid, if the aerated alkali be used: the phlogistified alkali yields a dark blue precipitate.

(H) Tin is precipitated white by every alkaline salt, even by the phlogistified alkali; but at length some blue particles, which are mixed, appear, so that the whole, when collected and dried, is of a light blue colour. That these blue particles depend upon iron is easily seen upon calcination, for they become ferruginous, and obey the magnet. I have always found in tin an admixture of iron.

(I) Bismuth is precipitated white by water and alkalis, particularly the former; phlogistified alkali throws down a yellow powder, which being mixed with blue particles, occasioned by iron, at length appears green. This yellow sediment easily dissolves in nitrous acid.

(K) Nickel is precipitated of a whitish green by fixed alkalis; by the phlogistified alkali of a yellow; and by exsiccation it is condensed into a dark brown mass.

(L) Arsenic dissolved in acids, which prevent too great dephlogistification, may, to a certain degree, be precipitated white by the fixed alkali, even when phlogistified, but the sediment is found soluble in water; yet nitrous acid, either alone or joined with the

(M) (Q) marine,

marine, generally dephlogistidates the arsenical acid, which thereby becomes unfit for separation. Arsenic, dissolved in marine acid, with the addition of a little nitrous acid deposited a white sediment; upon the addition of a large quantity of phlogisticated alkali, the sediment was mixed with Prussian blue; this was dissolved in water, and freed by frequent filtration from the blue particles, and at length, on evaporating to dryness, yielded a semipellucid mass.

(M) Cobalt, dissolved in acids, is thrown down by fixed alkali, whether aerated or caustic, of a reddish blue, which colour, on exsiccation, grows darker, especially when the former alkali has been used: phlogisticated alkali throws down a powder of almost the same colour, which, upon exsiccation, becomes of a reddish brown.

(N) Zinc is precipitated white by aerated and caustic fixed alkali, as also by the phlogisticated alkali; but this last, on exsiccation, becomes of a citron colour: a small portion of aerial acid may easily escape during the precipitation.

(O) Antimony is precipitated white by alkalis, when the phlogisticated alkali is used; at the same time almost always some blue particles are precipitated, although the regulus had been prepared without any iron. The operation should be cautiously conducted, lest some part be taken up by the alkaline salt.

(P) Man-

(F) Manganese, which is procured by reduction from common magnesia nigra, generally renders menstrua brown, and with aerated alkali yields a yellowish brown sediment; with the caustic, one still darker; with the phlogisticated, a powder is separated, at first a blue one, then a white, the mixture of which renders the mass a darkish or rather a black green. That the calx of the manganese may be obtained pure and white, the precipitate occasioned by caustic alkali must be dissolved in pure vinegar; for there still remains a quantity of undissolved iron, which is taken up by the aerial acid. This acetous solution contains little or nothing of iron. That metal may also at first be separated by a small quantity of volatile alkali.

The common solution of the regulus is not perfectly precipitated by aerated alkali; and, upon the remaining liquor spontaneously evaporating to dryness, upon the glass are deposited grains of a metallic splendor, and not unlike copper. These are readily, though but partially, dissolved in nitrous acid; but upon the addition of zinc, nothing but the manganese falls, though at first it is a little reddish. With phlogisticated alkali, a yellow precipitate, like pure manganese, falls, provided the solution has deposited the iron when too much dephlogisticated by age; but the new solution yields a precipitate almost like that which

is obtained from common regulus. The yellow sediment may be dissolved in water.

There is always a considerable difficulty attends the describing of colours, as the several varieties, which are almost innumerable, are destitute of particular names. Colours are indeed subject to changes, but not the smallest ever occurs without some determinate cause; they should therefore be carefully observed, for from thence we shall always learn something, provided we consider every thing with due attention.

§ VI. *Nature and Composition of Metallic Precipitates.*

The metallic precipitates will reveal to us many mysteries upon proper examination.

(A) Our first inquiry shall be concerning their weight. I have as yet only examined those precipitates which are occasioned by aerated mineral alkali, caustic alkali, and phlogisticated alkali. The results of many of those experiments I have been obliged to reject, as being too vague and indeterminate; the rest I hope are somewhat better founded. But upon considering how difficult it is to depurate and wash completely the metallic sediment, so that neither the alkali, the aerial acid, the water, nor any other extraneous matter shall adhere, I consider them only as collections of the first terms of infinite series,

series, which converge very quickly.—In order to obtain the nearest possible approximation, I repeated the experiments frequently in the most accurate manner, and they are here subjoined. In the following table 100 parts of the metallic regulus are always supposed dissolved.

100 parts of Gold, precipitated by aerated mineral alkali	caustic	—	yielded	106
—	phlogificated	—	—	110
—	martial vitriol	—	—	100
Platina,	aerated mineral alkali	—	—	34
—	caustic	—	—	36
—	phlogificated	—	—	129
Silver,	aerated mineral alkali	—	—	112
—	caustic	—	—	145
—	phlogificated	—	—	133
—	salited	—	—	134
—	vitriolated	—	—	110
Mercury,	aerated mineral alkali	—	—	104
—	caustic	—	—	—
—	phlogificated	—	—	—
—	vitriolated	—	—	119

100 parts of Lead, precipitated by		Dry Precip.	
		yielded	
caustic	—	132	—
phlogisticated	—	116	—
vitriolated	—	—	143
aerated mineral alkali	—	—	194
caustic	—	—	158
phlogisticated	—	—	530
aerated mineral alkali	—	—	225
caustic	—	—	170
phlogisticated	—	—	590
aerated mineral alkali	—	—	131
caustic	—	—	130
phlogisticated	—	—	250
aerated mineral alkali	—	—	130
caustic	—	—	125
phlogisticated	—	—	180
pure water	—	—	113

Nickel,	—	aerated mineral alkali	—	135
—	—	caustic	—	128
—	—	phlogisticated	—	250
Arsenic,	—	aerated mineral alkali	—	—
—	—	caustic	—	—
—	—	phlogisticated	—	180
Cobalt,	—	aerated mineral alkali	—	160
—	—	caustic	—	140
—	—	phlogisticated	—	142
Zinc,	—	aerated mineral alkali	—	193
—	—	caustic	—	161
—	—	phlogisticated	—	495
Antimony,	—	aerated mineral alkali	—	140
—	—	caustic	—	138
—	—	phlogisticated	—	138
Manganese,	—	aerated mineral alkali	—	180
—	—	caustic	—	168
—	—	phlogisticated	—	150

(B) Upon

(B) Upon comparing these weights, a question at first occurs concerning the cause of such enormous differences; and it is plain that this cause must be sought for in the precipitates themselves. The fixed alkali, saturated with aerial acid, when added to the solution, is taken up by the more powerful menstruum, and the weaker is of course expelled, and is absorbed by the calx, as it falls in greater or lesser quantity, according to circumstances. That this is actually the case is easily demonstrated:—let a bottle, containing a sufficient quantity of nitrous acid, be accurately weighed; let there be put into it by degrees, *e. g.* 132 parts of lead, precipitated by aerated alkali, and not only an effervescence will be observed, which continues until the very last particle is dissolved; but when the solution is finished a deficiency of weight is discovered, which amounts nearly to 21, and which is indubitably owing to the extrication of aerial acid (§ III. E). But $132 - 21 = 111$, a weight which still considerably exceeds that of the metal. Upon distillation nearly 8 of water are discovered; there yet remain therefore 3, which by violent heat are increased by 7; for 132 of the calx, well calcined, yield 110. The whole increment of weight then does not depend upon the water and aerial acid. The same thing is evinced from the consideration of the precipitate of lead by the caustic alkali, as it is evident that in this case there is

is no aerial acid; besides, no effervescence accompanies the solution. If we suppose the quantity of water equal in both cases, yet, even on this supposition, the whole excess is not accounted for, for $116 - 8 = 108$. It is therefore probable that the matter of heat is attached to the calx. This matter of heat is always present in caustic alkali; for when it is dissolved in the simple acids, heat is always generated. This opinion is confirmed by the following considerations: 1st. The increment of weight can scarce be conceived, without supposing an increment of matter. 2d. When the caustic alkali is employed no other matter can be suspected. 3d. The same cause is also present when the weight is increased by dry calcination. 4th. Let the heat occasioned by the mixture of determinate portions of any acid and caustic alkali be marked upon a thermometer: let then an equal quantity of the same menstruum be saturated with a metal; afterwards, upon the addition of an equal quantity of caustic alkali, it will be found either that no heat is generated, or a degree very much less than before. Some of the matter of heat therefore is taken up and fixed, which also generally makes the colours of the precipitates more obscure, and in distillation with sal ammoniac communicates to the volatile alkali the quantity that had been taken away. What has been said of lead is also true of the other metals, a few excepted,

which seem to take up little or no aerial acid; these are tin, antimony, gold, and platina.

(c) But some precipitates *retain also a quantity of the menstruum*. Thus, corrosive sublimate, precipitated by aerated alkali, retains a portion of marine acid, which cannot be washed off by water; but by caustic alkali the precipitate may be obtained, either free of the acid altogether, or in a great measure. In this case, as in many others, the aerial acid seems to generate a triple salt, which is scarcely soluble. The presence of the marine acid is easily discovered by nitrated silver, if the precipitate be previously dissolved in pure nitrous acid. Hence we observe another difference in mercury precipitated from marine acid, according as aerated or caustic alkali has been employed: the latter precipitate, well washed and put into volatile alkali, is scarcely changed in colour; but the former instantly grows white, generating a species of sal alembroth, but containing so little marine acid as not to be easily soluble in water.

The calxes, which retain any of their former menstruum, generally give over on distillation a small portion of a sublimate. The mercurial calx, just mentioned, exposed to a sufficient degree of heat, is partly reduced to crude mercury, partly to mercurius dulcis, by means of its remaining marine acid. This mercurius dulcis did not exist in the
 10 precipitate;

precipitate; for in that case it would be easily discovered by acids, in which it is not soluble, and would grow black with caustic alkali, neither of which things takes place; it is therefore generated during the distillation.

(D) The nature of phlogisticated alkali is as yet obscure, but it possesses the same properties, with regard to salts and alkaline earths, as acids when loaded with phlogiston do:—the same is true with regard to metallic calxes, with which it forms compounds of a saline nature, though most of them are insoluble in water.

§ VII. *Advantages resulting from the Examination of metallic Precipitates.*

In order to recommend the more accurate examination of metallic precipitates, I beg leave to add a few words concerning the advantages to be derived from that labour.

(A) It is evident that by more intimate acquaintance with these precipitates, the chemical theory of the operation will be better understood.

(B) We may thereby be able to discover the more useful and remarkable properties. No one is ignorant that aurum fulminans, the mineral purple, and other encaustic pigments, by which the colours of gems may be imitated, have been derived from this source.

(c) A foundation is thereby laid for the art of assaying by the humid way, from the bare knowledge of the weights. It may be objected, that the doctrine of the weights is very fallacious; that they vary in the different precipitates; that by imperfect precipitation something remains in the liquor; and that sometimes extraneous matters are mixed with them. All this is true; but if the mode of operation be always the same, the results of the experiments will be constant. Let us suppose that a quantity of metal (a), precipitated in a certain manner, makes a weight (b); if that same manner be exactly employed, we may fairly conclude that a quantity of precipitate (n b), occurring in any case, is correspondent to a quantity of perfect metal (n a), although in the fundamental experiment either the precipitation is incomplete, or some extraneous matter be present. If all the circumstances which occasion increase or deficiency be carefully attended to, the conclusion will remain unimpeached: let the method therefore be accurately determined, and there will be no danger of fallacy.

(d) By this the nature of metals is illustrated. Platina, nickel, cobalt, and manganese, are suspected by some persons to derive their origin from a mixture of other metals. But if iron necessarily enters into the composition of platina, when this is dissolved in aqua regia it should produce a Prussian blue

upon the addition of phlogisticated alkali; and this is the case in fact when common platina is employed, but not when it is rightly depurated (*w*).

If iron, adhering very obstinately to nickel, formed a great part of it, the precipitates obtained from it by alkalis could not differ from martial precipitates so much as they do, in colour, weight, and other properties.

The same is true of cobalt and manganese. The regulus obtained from magnesia nigra contains about 0,08 of iron: let us see how this affects the mixture.

100 dissolved in an acid menstruum yields to phlogisticated alkali a powder, consisting partly of blue, partly of brownish yellow particles, which is equal in weight to 150 lb.; but 8 lb. of iron yield 48 of Prussian blue, nearly $\frac{1}{3}$ of the whole mass: hence it follows, that 100 parts of pure manganese yield to phlogisticated alkali scarcely 111, *i. e.* nearly six times less than an equal weight of iron.

(E) Finally, it may by this means perhaps be possible to determine the unequal quantities of phlogiston in different metals; for a given weight of precipitating metal does not yield an equal quantity of precipitate: thus, *e. g.* copper is able to precipitate from nitrous acid four times its own weight of silver.

(*w*) Treatise on Platina, § VII. (G).

DISSERTATION XXIV.

OF THE

ART OF ASSAYING

IN THE

HUMID WAY,

§ I. *Circumstances attending assaying by the dry Way.*

THERE is no doubt but ores were dug up, and their metallic contents extracted, long before the invention of the docimastic art; but the superior industry of later times has discovered the necessity of making trials in small, by which the quality and goodness of the ore being previously known, unnecessary expence may often be timely guarded against; and, as the great works are effected by means of fire, it was
thought

thought proper to employ the same agent in the lesser experiments. The first attempts certainly were extremely rude, but repeated and collected trials have gradually advanced it to the form of a science, or rather of an art, which although, no doubt, long concealed in the laboratory, was not published until the middle of the 16th century. The first book upon this subject is generally attributed to Lazarus Ercker; this was published in 1574. But Agricola, in his seventh Book *de re Metallica*, published in 1576, described both the instruments and the processes, and illustrated them with plates. And from the preface to the *Ars Docimastica* of Modestinus Fachs, it evidently appears, that the manuscript had been presented, in the month of March 1567, to the elector of Saxony, though it was not published until after Ercker's book. In process of time this art became far more perfect; but we have not leisure to pursue it through its successive states of improvement.

In the *docimasia sicca* three circumstances are necessarily required;—1. *That the metal contained in the ore be all reduced to a complete form*; for such part of it as is deficient in that respect, cannot be united with the eliquated metal. 2. *That the same be collected into one mass*; for when it is in the form of numerous small grains, some of them are very easily scattered, and diminish

the weight. 3. *That the metallic form once induced be preserved*; for the extracted regulus must inevitably be diminished more or less by calcination.

All these requisites are frequently effected commodiously and perfectly enough by fusion in a crucible with proper strata of charcoal, provided the ore is free from sulphur, and every other volatile mixture, and is either entirely without a matrix, or united to one which is fusible by a moderate degree of heat; but if the matrix be refractory, notwithstanding the most subtile pulverization it will cover many metallic particles, and thus prevent their reduction and fusion. In this case it is necessary to employ such additaments as not only promote fusion, but occasion such a degree of tenuity as may suffer the reguline particles to fall to the bottom. To this they are naturally disposed by their great specific gravity; but, nevertheless, if the mass be tenacious or thick, and especially if they themselves be small and discrete, they are kept floating by the great friction which is to be overcome in their descent. These additaments, which from their effect are called fluxes, are of a saline nature, and must therefore necessarily corrode the metals more or less; and hence the scoriæ, which are almost always tinged, contain a quantity of calcined metal.

But, *so long as we are destitute of a sure method of measuring intense degrees of heat,*
and

and so long as it is necessary to perform the operation in close vessels, to prevent the access of air, so long will the force and proper continuance of the fire be, as it has hitherto been, uncertain. Now, by every excess or defect in this point, somewhat of the regulus is lost; so that any judgment of the goodness of the ore, formed from the weight of the regulus, must be fallacious and uncertain, or at least somewhat inaccurate.

All this sufficiently shews, that experiments made in the dry way are still liable to many faults and imperfections; to which we may add some more; *viz.*—Any given quantity of ore, subjected to trial, almost always exceeds the regulus to be extracted from it very much in weight. Now, since it is almost impossible to avoid a certain loss during both calcination and fusion, this loss will be the more remarkable as the mass ultimately to be weighed becomes lighter. The case is quite otherwise with experiments made in the humid way; for here the weight of sediment, from which the quantity of the content is judged, is never less, but often greater, than that obtained by fire. Let the loss sustained in examining equal quantities of ore in both ways be the same, and denoted by (n) ; let the quantity of regulus, obtained by fire, be expressed by (a) ; that of the sediment collected in the humid way by $(m a)$; and the true value
of

of the regulus will be $a + n$. This being supposed, as (m) is never less than unity, it is obvious, that, except in case of equality, $n : a > n : ma$; and, besides, that (n) is the more diminished in respect to (ma) in proportion as (m) exceeds unity the more. The examples occurring hereafter will illustrate this truth more at large.

§ II. *General Observations to be made in conducting the Process of assaying by the Via Humida.*

Chemistry has at length begun to examine the composition of ores by means of various menstrua; yet it must be confessed, that the fragments of the humid art of assaying, which have hitherto been published, are rather to be considered as instances of a mixed method, in which the mineral analysis is accomplished partly by the dry, partly by the humid method. The metallic part is indeed extracted by a menstruum, but is afterwards reduced by fire. In the following pages, however, I shall endeavour to point out means by which the end may be answered in the humid way alone, without calcination or fusion. — It is by no means my intention to depreciate the dry way. In practice, the most commodious and most accurate processes ought always to prevail; but a due comparison of these two methods can never be instituted, nor the best

best methods of operation chosen, so long as either remains clogged with difficulties and impediments. In the prosecution of mineral analysis, it is therefore of the highest moment to remove these difficulties; for the *docimasia sicca* conceals and confounds many of the heterogeneous admixtures; and if, by means of the humid way, these can be all segregated and determined as to quantity and quality, not only much light will be thrown on mineralogy and metallurgy, but the true foundations of these sciences laid, as any person who is not entirely ignorant of them may readily perceive. Very often it is useful to know, not only the heterogeneous metallic substances, which sometimes, to the amount of three or four, are mixed with the extracted regulus, but frequently, also, the occult earthy matrix; and yet neither of these can be accurately discovered, except in a very few cases, by the dry method, as it has hitherto been practised; for it is evident, that in fused masses the admixtures which ought to be removed, are the better protected by the genuine materials in proportion as the former are more diminished; a circumstance which cannot take place in solutions, which may be diluted *ad libitum*. It must indeed be confessed, that experiments in the humid way often require more time, more care and pains; but if accurate conclusions are thereby supplied, we should not be difficult about

about slowness. Besides, in many cases this method is more expeditious than the other; and that indeed almost always, if we are content with such discoveries as can be made by the common calcinations and fusions; nay, sometimes the dry method is obviously insufficient, when the metallic content is either very small or volatile, but particularly if it be inflammable, as is the case with zinc.

In the following experiments an assay cwt. was always employed, unless where it is expressly mentioned otherwise. Conclusions sufficiently accurate may indeed be often obtained from 25 lb. nay sometimes from smaller quantities. In these cases I have mentioned the usual quantity, applying to them those formulæ of calculation which are founded on the mutual proportions of the proximate principles constituting metallic salts, and which are determined in another place (a) from the weights of metallic precipitates. By an easy substitution the same formulæ may be used by those who employ $\frac{1}{4}$ or $\frac{1}{2}$ cwt.

The ores to be examined should be reduced to a very subtile powder by pulverization and elutriation.

The solutions of such ores as contain sulphur require much caution: if possible,

(a) See the Treatise on the Analysis of Waters, § xi and this Treatise, § vi.

the vitriolic or marine acid should be employed; for by continued heat the nitrous acid destroys the sulphur: by too violent an heat, also, some of it is dissipated in vapours, or is melted into globules containing heterogeneous matters; therefore, if it can be done, boiling should be avoided.

All the precipitates must carefully be washed, collected, dried, and weighed, as is obvious. It is sufficient here to mention this, to avoid the trouble of repetition. Distilled water should constantly be used, and all the menstrua carefully depurated. I call vitriolic acid diluted when its specific gravity is below 1,3; nitrous, when below 1,2; and the marine, when below 1,1.

The precipitations should be carefully made (in glass vessels), so that neither by the deficiency of the precipitant shall any thing remain in the menstruum, nor by its abundance any thing be re-dissolved. The clear liquor is to be decanted from the sediment, water poured on in its place, the vessel shaken, and then suffered to stand; the water again decanted off, and fresh poured on, until it no longer can affect certain precipitants by which it must be examined.

This being done, the sediment is to be collected upon a filter (first weighed) made of paper not impregnated with alum, dried at first with a gentle heat, but after exposed for five minutes in a close glass vessel to 100° of heat; upon cooling it is to be weighed, together

gether with the filter, the known weight of which must afterwards be subducted. The best method of washing the sediment is in a bottle; for the filter, when once filled with a saline solution, is not without great difficulty freed from it, especially if there intervenes a delay of some hours.

When I speak of an alkaline precipitant, the mineral alkali, charged to saturation with aerial acid, is always to be understood.

The alkali, which is commonly called phlogisticated, I always prepared in the same way — equal weights of the purest nitre and cream of tartar, well pulverized and mixed, are heated in the usual way and detonated. The common white flux is thus procured:—half an ounce of this is dissolved in a cucurbit, in half a quadrans of distilled water; then in a digesting heat are gradually added two ounces of Prussian blue, carefully avoiding such an effervescence of the liquor as may throw any thing over, which easily happens if the quantity be too large: the pigment soon loses its beautiful colour, not growing red but black, which evidently shews that a complete decomposition has not taken place. The Prussian blue for sale, is not always found of the same quality. That which was used in the following experiment, contained in 100 parts 77 of clay, and only 23 of the pigment; so that if it be thought proper to employ the blue made without any alum, 221 grains will

will saturate the half ounce of alkaline salt more completely than the two ounces above prescribed, and the bulk of the residuum is thereby also lessened. Whatever way the operation be performed, after the addition of the last portion the whole must be exposed to a stronger digesting heat, and the mass often stirred with a wooden rod : if the liquor be too much diminished by evaporation the defect must be supplied by warm water. At length the lixivium becoming clear, let the residuum be collected on a filtering paper, and gradually washed with warm water until all the soluble part is separated. If the operation be rightly conducted, the clear liquor amounts to an whole quadrans, of a brownish yellow, and so saturated as not to make paper tinged by Brazil wood blue; hence the colouring principle united to the alkaline salt seems to be of an acid nature; but the Prussian blue, and other metallic precipitates of the same kind, always yield on distillation, besides an unctuous matter, a distinct volatile alkali.

The lixivium saturated with the colouring matter contains also a small portion of perfect Prussian blue, about 4 lb. to a cwt. of the alkaline salt; which are separated on the addition of the acid: these should be previously separated, or, what is better, corrected, by subducting from the weight of the sediment 16 assay pounds for each quadrans of the lixivium. When the question is about a distinct

distinct colour in the precipitate, the lixivium must necessarily be employed well depurated: those who neglect this precaution, readily persuade themselves that any metal, precipitated by our lixivium, can put on the blue colour. But if the question be only about the weight, let the lixivium, still loaded with a small portion of Prussian blue, be dropped; however, the proper correction must ultimately be employed; for the precipitating acid, in a short time, is wont also to weaken the properties of the lixivium, and even to destroy them, especially in a warm temperature. Lime, whether aerated or caustic, is also capable of abstracting a colouring substance from iron and other metals. We shall perhaps speak in another place more at large of the qualities and properties of these combinations, here we only treat of their preparation and use.

In the precipitating of metals by metals, it is to be observed, that the acid of the solution ought to be somewhat predominant; but any more considerable excess must be corrected occasionally, either by alkali, water, or spirit of wine.

§ III. *Ores of Gold.*

Gold occurs in the bowels of the earth native, possessing a compleat metallic form, although in general the small particles of it
are

are so interspersed in various matrices; that they are entirely invisible; it is also found mineralized, that is, united with sulphur, by means of iron, or some other metal. These two species of ore we shall consider separately.

(A) Native gold is very seldom, if ever, entirely free from heterogeneous matters; the most usual inquinaments are copper, silver, and sometimes iron. The first of these remains in the menstruum, and may be separately collected, if the gold be dissolved in aqua regia, and precipitated by martial vitriol (§ VIII.); the second falls during the solution, yielding a salited silver, which, washed and dried, shews the weight of the silver contained (§ V.); finally, the last is discovered by a phlogisticated alkali, and is estimated in a manner elsewhere described (§ IX.). The precipitate occasioned by the martial vitriol is pure gold in its metallic form, although very subtilely divided; and therefore the weight found requires no correction.

From the preceding and following circumstances it appears, how a small portion of gold, inhering in the ores of other metals, may be extracted; besides, a solution, containing the most minute particle of gold, instantly produces the purple precipitate of Cassius, with a solution of tin properly prepared.

(B) As to the ore which contains gold adhering to and surrounded by stony particles, first a determined weight is to be reduced to an impalpable powder, by triture and elutriation.

Then let the powder, weighed a second time, be boiled in aqua regia, so long as any thing is taken up by the menstruum; after which let the exhausted ore, well washed, be collected, exsiccated to ignition, and weighed.

Let the clear solution (the colour of which in some degree affords a method of judging) be precipitated in the usual way by martial vitriol; the precipitate well washed, dried, and weighed, shews the gold, which, added to the weight of the exhausted ore, ought to equal the original weight, unless somewhat has been dispersed by the pulverization, or unless some of the matrix has entered the menstruum: the former of these is discovered by comparing the weights before and after pulverization, the latter by precipitants.

When grains of gold are mixed with loose earthy particles, they are sometimes easily separated by mechanical application of water.

(c) Let one or more assay cwts. of the golden pyrites, reduced to powder, be gently boiled in diluted nitrous acid, or rather digested in an heat of 50° — 80° , lest the sulphur should be destroyed; a gentler heat even is necessary

necessary for this purpose, that the sulphureous particles, gradually separating, may remain in their natural state; for if they fuse, the heterogeneous particles, which ought to be removed, will be included in the fused mass.

This operation must be so conducted, that the menstruum may be added in several portions, at each turn about six times the weight of the ore; this attacks the pyrites with an effervescence, occasioned by the extrication of a large quantity of nitrous acid. When this effect ceases, another portion is to be poured on, until the sulphur is obtained pure, and marked with its genuine colour. This process generally requires to one part of the ore from 12 to 16 of the acid.

Let the sulphur, when washed, be collected upon a filter, dried, and weighed: whether it be pure or not is easily determined by the caustic fixed alkali.

If the matrix is insoluble in the menstruum, it remains at the bottom, together with the gold, which is distinguished by its peculiar splendor and colour, and may be separated from the powder of the matrix by careful elutriation. The particles of gold do not assume the form of impalpable atoms, but of grains, very small indeed, but such that a discerning eye will readily observe their angles and inequalities; and their appearance may perhaps lead to a suspicion

that they have been rather mixed with, than dissolved by the pyrites.

The clear solution is generally green ; let this be evaporated to dryness, then ignited and weighed. If there be other metals besides iron present, they may be extracted by suitable menstrua ; copper by the volatile alkali ; manganese, which is generally present, by dilute nitrous acid, with the addition of a little sugar ; zinc by any menstruum, although this is scarcely ever found in gold pyrites ; and silver by pure nitrous acid. When calcareous earth forms the matrix, it unites with nitrous acid, and yields a nitrated lime ; when clay, it forms an alum with vitriolic acid.

The sum of the weights of all the ingredients should be equal to the original weight ; and, unless some loss has been sustained during the operation, any deficiency is to be attributed to the sulphur destroyed.

(D) I have as yet only seen one specimen of the ore of Nagyay ; this consists of a grey quartz, and a white matter not unlike a sandy stone, which is taken up with effervescence by acids, without imparting any tinge to the menstruum. The solution forms, with aerated alkali, a white precipitate, and with phlogisticated alkali a brownish yellow. By the dry method the same matrix soon grows black in the fire,
I and,

and, according to circumstances, tinges microcosmic salt either with a purple colour, or does not tinge it at all; it is therefore (b) an aerated manganese. This matrix contains dispersed in it lamellæ of the colour of lead, or a little darker, which yields to the knife: these, with warm aqua regia, grow quickly white, and are totally dissolved with effervescence, tinging the menstruum yellow; on cooling, the solution deposits acicular crystals. If we were provided with a sufficient quantity of the ore, I have no doubt but its constituent principles might be separated in the humid way by proper menstrua.

§ IV. *Ores of Platina.*

So far as we know, the metal called platina is not found any where but in America, and is always native. The only metal with which this is constantly alloyed is iron, the greatest part of which may be separated by repeatedly boiling the grains of platina, reduced to as fine a powder as possible, in marine acid; in this way the original weight is generally diminished about 0,05.

The platina, being thus depurated, and dissolved in aqua regia, easily discovers itself

(b) Treatise on the White Ores of Iron, § VII.

by means of martial vitriol, if any gold be present : on the other hand, if platina contains a small portion of gold, this may, for the most part, be precipitated by any neutral salt, containing vegetable or volatile alkali.

§ v. *Ores of Silver.*

Silver, besides its complete form, puts on in the bowels of the earth a variety of forms, partly united with sulphur, either alone or with other metals, partly mineralized by acids.

(A) Native silver is generally allayed with gold or copper, or both ; the silver and copper are easily taken up by nitrous acid ; and if any gold be present, it appears at the bottom like a black powder, which by solution in aqua regia, and precipitation by martial vitriol, may be made at pleasure to assume a more metallic appearance.

This separation being effected, the copper remaining in the liquor may easily be collected by means of iron, or aerated alkali.

There has lately been discovered a new variety of silver ore, which is extremely rich ; this is found in two different places, namely, at Andreasberg in Hercynia, and at Wittichen in Fustenberg ; a specimen of each is to be seen in the Academy's collection. That of Fustenberg has the appearance of

of irregular grains conglomerated, which possess a metallic splendor, are a little yellow, and, together with native silver, are contained in the common white spathum ponderosum. The grains, when examined, are found to contain silver allayed with a small portion of regulus of antimony. These metals may be separated by concentrated nitrous acid; for the first is thereby dissolved, and the latter corroded into a white calx. Aqua regia takes up the antimony, a salited silver remaining at the bottom. The particles of this ore are somewhat malleable, and should be reduced as fine as possible before they are put into the menstruum. The ore of Hercynia is called butyraceous; that which I have seen, exhibited, in a calcareous matrix, very thin leaves of metal, the scarcity as well as tenuity of which, in the above-mentioned specimen, prevented me from making proper experiments; so that I dare not absolutely affirm that this agrees with the former in its properties, although it appears very probable.

(B) Silver united with sulphur alone is black, and is commonly called the glassy ore of silver. Let this, divided and comminuted as much as possible, be gently boiled for an hour in 25 cwt. of diluted nitrous acid; the liquor being decanted, let the operation then be repeated with an equal quantity of the menstruum; and unless the pure sulphur be now separated, the men-

struum is to be employed anew : the last particles of the silver adhere obstinately to the sulphur : if any gold be present, it remains undissolved at the bottom.

The decanted liquors being collected, are to be deprived of the silver by the addition of common salt ; let this, when collected, washed, and dried, be = a, and the silver required will = $\frac{100\ a}{129}$.

Let the sulphur be weighed separately, and its weight, added to the above, should amount to lb. 100, if the operation has been rightly performed, and no decomposition of the sulphur has taken place.

The clear liquor which passes in filtering the luna cornea, upon the addition of a phlogisticated alkali quickly discovers the foreign metal accidentally inhering in it : and after this precipitation the earthy contents are exhibited by a fixed alkali. The reliquæ of the insoluble matrix are with difficulty separated from the sulphureous particles :—let the sum of the weights be first enquired, then let caustic alkaline lixivium be poured on, and the sulphur dissolved in a gentle digesting heat ; the matrix then remains alone, and its weight determines that of the sulphur. The digestion must not be continued longer than is necessary, for the siliceous earth is also capable of entering the lixivium. However, this inconvenience is not very much to be apprehended, for to this effect

effect the mechanical division must be far more completely performed.

(c) Silver, united to sulphur and arsenic jointly, is generally distinguished by its red colour, sometimes beautifully pellucid, resembling a ruby; but it is sometimes grey, metallic, and opake. All these varieties however yield a red powder, and hence it is called the red ore of silver.

Let this, reduced to a very subtile powder, be twice gently boiled in diluted nitrous acid as above: a part of the menstruum being decanted off, let the white powder which remains at the bottom be well washed with distilled water: let the silver be precipitated from the clear liquors, collected by means of sea-salt; and finally, let the salited sediment, properly treated, be weighed as before.

Let the white powder above mentioned be quickly boiled in a sufficient quantity of aqua regia, until the arsenic be dissolved, and the sulphur appears pure. The yellow solution, cautiously decanted, lets fall a very white powder, upon the addition of a suitable portion of water; and the small quantity which is taken up by the water is collected by evaporating to dryness.

The sulphur now separated, though it appears pure, yet still contains a little silver, which could not easily be separated before by the nitrous acid, on account of the arsenic; but when the arsenic is taken away
by

by the aqua regia, the remaining parts of the silver are taken up by the marine acid, entangled in sulphureous particles. In order therefore to free the sulphur from this salited silver, let caustic volatile alkali, diluted with water, be poured on, and kept in a well-closed vessel for some days—a weight of the alkaline liquor equal to that of the sulphur is sufficient. The sulphur being weighed before and after the operation, indicates the weight both of itself and of the salited silver.

If any iron be present, which I have seldom experienced, it may be discovered in the liquors first precipitated with the salt or water, by means of phlogisticated alkali.

(D) Silver united with sulphur, arsenic, and copper, is generally called the white ore of silver, and is examined in the following manner:—let 1 cwt. of the ore, reduced to powder, be gently boiled for an hour in a little more than twelve times its weight of diluted nitrous acid. The dry powder grows black and foul; and, when added to the acid, sends forth an hepatic smell, a portion of it is dissolved, and at length a white residuum remains at the bottom: upon subsiding, if the liquor cannot be decanted clear, let it be filtered. This liquor contains the silver and the copper; the former of these cannot be precipitated alone by muria, because the marine acid attracts the copper more strongly. A white precipitate, composed

posed of small aciculæ, is indeed thrown down; but upon exposure for some days to the rays of the sun, does not grow black in the smallest degree; and it consists of a peculiar combination of marine acid, silver, and copper. The silver therefore in this case is to be precipitated by a determined weight of copper; and afterwards the copper to be separated by iron or aerated alkali (§ VIII.); but the ultimate weight is to be diminished by that of such part of the precipitant as has entered the menstruum.

Let the white residuum be boiled in marine acid, and precipitated by water; thus we obtain the arsenic with a small portion of marine acid, which yet it retains obstinately, as is elsewhere observed.

The arsenic being separated, the sulphur remains alone, and must be proved by volatile alkali, to try whether it still contains any copper or salited silver.

(E) Silver mineralized by sulphur, sometimes also contains antimony: this ore often forms capillary threads of an hoary brown colour: let this be gently boiled, or rather digested, for an hour, in six times its weight of diluted nitrous acid, until the silver is dissolved, and all the antimony reduced to a white calx, which, after decanting the liquor, may be separated from the sulphur by marine acid, and precipitated by water. The solution of silver is to be precipitated by

by muria, and 1 cwt. seldom contains more than four ounces.

(F) Besides sulphur and antimony, there is sometimes also present copper and iron; but the experiment in this case may be conducted in the same way, only with a double proportion of acid. These metals all remain in the liquor, but are easily separated by precipitating the silver, by means of copper; and the iron by zinc, or an alkaline salt.

(G) We sometimes meet with silver mineralized by sulphur at the same time containing iron: but in the ore which the Germans call *weisertz* silver is frequently absent, so that the silver which is sometimes discovered in it seems to be native.

(H) Silver, mineralized by the marine and vitriolic acids, is commonly known by the name of corneous ore of silver: the colour of this is white, green, yellow, violet, or black. Two remarkable varieties of it occur, the one may be cut, and is somewhat malleable; the other brittle, which, besides the acid, also contains sulphur.

Let 100 of the former, comminuted as much as possible, be plunged into marine acid, and kept for one day in a digesting heat, shaking the mixture from time to time: let the liquor be afterwards decanted clear, and the residuum, previously well washed with water, be added to the liquor: then let nitrated terra ponderosa be gradually
dropped

dropped in, until it ceases to occasion any precipitation. Suppose the weight of the precipitate, washed and dried, = a ; now vitriolated terra ponderosa, whose weight is a , contains of acid $0,15 a$, which corresponds with vitriolated silver $0,48 a$; for from 100 of vitriol of silver 68,75 of metal is obtained by reduction. All the silver is not precipitated from nitrous acid by the vitriolated mineral alkali: the salited silver therefore, will be $100 - 0,48 a$. In the former salt the silver contained is expressed by $0,33 a$; in the latter by $75,19 - 0,36 a$, and therefore the sum required for the 100 will be $75,19 - 0,03 a$. These and the following formulæ depend upon the mutual proportion of the principles, and the weights of the precipitates, which are experimentally determined in the Tract on metallic Precipitates (§ VI. A).

The brittle horny ore also contains sulphur, but the saline part may be extracted by volatile alkali, and the quantity of silver afterwards determined by the method above mentioned (c).

(c) Artificial salited silver may, without any considerable loss of the metal, be reduced in the following manner:—let the mass be mixed with an equal bulk of alkaline salt in a glass mortar, and by means of a few drops of water be formed into a globule; let this globule be put into a crucible, the bottom of which has previously been strewed with sal sodæ, compressed, and well covered with the same alkali; an heat sufficient for fusion being then applied, the whole of the metal will be recovered if the salited silver has been accurately collected.

§ VI. *Ores of Mercury.*

Mercury is afforded by nature, either native or mineralized by sulphur or acids.

(A) When native it is easily distinguishable by its fluidity, and is seldom mixed with any other metals but gold, silver, or bismuth, which frequently exist native, and are very easily soluble by this liquid metal; if any of these be present, the first remains at the bottom, when the mercury is dissolved in nitrous acid; the third is indeed taken up by the menstruum, but precipitated by water; and the second is discovered by sea-salt, which also precipitates at the same time a saluted mercury, which is easily separable by its greater solubility.

(B) In cinnabar the union between the sulphur and the metal seems to be more complete than in other mineralizations, as it cannot be decomposed either by vitriolic, nitrous, or marine acid. I have even attempted to disunite them by a solution of caustic fixed alkali in water, and by boiling for many hours, but in vain. However, there are two ways of effecting a perfect decomposition; one by gently boiling for an hour the cinnabar with eight times its weight of an aqua regia, one fourth of which consists of marine acid; the other by boiling it in marine acid, with the addition of $\frac{1}{10}$ the cinnabar's weight of black calx of manganese.

manganese. In both cases the menstruum is the same, namely, a dephlogisticated marine acid; but in the first case the acid is dephlogisticated by the nitrous acid, in the latter by the calx of manganese; the former is however the best, as no heterogeneous matter is superadded.

By whatever method the metallic part of the cinnabar is dissolved, the separated sulphur may be collected by a filter, and the mercury precipitated by zinc: copper precipitates saluted mercury in a more imperfect manner.

If the cinnabarine ore under examination be very much entangled in the matrix, it must be freed from it as much as mechanically can be done by lotion; then the soluble parts of the matrix taken away by nitrous, marine, or vitriolic acid, occasionally; and finally, the metal itself separated by aqua regia.

(c) Mercury has also lately been discovered mineralized (d) by the vitriolic and marine acids. The former may be separated by the help of marine acid, by trituration or digestion, and the metal precipitated by nitrated terra ponderosa; but the weight of the new earthy salt a, being given, we can easily learn the quantity of metal (as before observed § v.): yet as nitrated mercury is not totally precipitated by

(d) Mr. Woulfe was the first who discovered that these two acids act as mineralizing substances with respect to mercury.

vitriolated mineral alkali, we must not here depend upon the weight of the precipitate: By another process, therefore, we obtained from 100 of vitriol of mercury 33,899 of pure metal, and from an equal weight of corrosive sublimate 75,5; from whence the data of a calculation are easily deduced: for, let the quantity of vitriolic acid = 0,15 a; the vitriol of mercury containing this = 0,44 a; and the salited mercury = 100 — 0,44 a. In the former salt the mercury constitutes 0,29 a, and in the latter 72,5 — 32 a; so that the whole metallic content in 100 = 72,5 — 0,3 a. But as the scarcity of this ore has not permitted us to examine it sufficiently, we are still ignorant whether the salited part is to be compared with corrosive sublimate or mercurius dulcis; if the latter, the calculation comes out different; for in the latter of these two salts the metal forms above 0,91, and the whole content is exhibited by the following formula; $91,18 + 0,29 a - 0,40 a = 91,18 - 0,11 a$.

§ VII. *Ores of Lead.*

Whether nature ever produces lead native is still in dispute. The most common ore contains it mineralized by sulphur, generally mixed with silver, sometimes also with iron and antimony together. That which is commonly called calciform lead, contains the

the metal united with the aerial acid, or the acid of phosphorus.

(A) Lead, if ever found native, may be easily examined as to purity, by means of nitrous acid, which discovers copper both by its blue colour and its precipitation by iron; and silver is betrayed by the addition of copper.

(B) When united with sulphur, and freed from any matrix, let it be reduced to a fine powder; let this be boiled in nitrous or marine acid until the sulphur is obtained pure, collected on a filter, washed, and dried. Its purity is ascertained by caustic fixed alkali.

Let the solution be precipitated by aerated mineral alkali, when the lead is either alone or mixed with silver; in the former case, supposing the weight of the precipitate = a , the weight of the reguline lead will be $\frac{100a}{132}$; if the latter, let the silver be extracted by volatile alkali, and the residuum multiplied into the constant coefficient $\frac{100a}{132}$ will express the lead. The aerated silver is known by the diminution of weight; if this be = b , then the silver in a metallic form = $\frac{100b}{129}$.

The solution made in marine acid during the operation deposits a large quantity of salited lead, which must be dissolved in water before the precipitation.

If antimony be present, this is so much dephlogisticated by concentrated nitrous acid, that it is calcined and falls to the bot-

tom : the given weight of this, multiplied by the constant coefficient $\frac{100}{111}$, indicates the regulus in the muriatic solution; this spontaneously falls, upon dropping in water, which takes up the salited lead.

Iron, which yet is but seldom found in galena, may thus be discovered :—let the muriatic solution be first so far saturated with fixed alkali that the acid may predominate only a little, and yet all precipitation be solicitously avoided. This being done, the lead will be precipitated by a polished plate of iron, added during boiling; as also will the silver, which is almost always present: finally, let the iron be precipitated by aerated or phlogisticated alkali (§ ix.); and its weight corrected by the part of the metallic plate which is dissolved during the precipitation.

If the ore contains any matrix, this is either soluble, and may at first be separated by vinegar, or else is insoluble in the common acids, and is found collected at the bottom.

(c) Lead, mineralized by aerial acid, and deprived of all heterogeneous soluble mixture, may be dissolved in nitrous acid, and precipitated by aerated mineral alkali; which being done, the quantity of lead is known by the weight of the precipitate, as before (B).

But if the matrix containing it be soluble, let the marine acid be employed, and

and the metal precipitated by iron, as above described.

(D) Lead, mineralized by acid of phosphorus, is easily distinguished. 100 of this, in powder, is dissolved in nitrous acid by means of heat, except a few martial particles, which generally remain at the bottom. The dissolved lead, upon the addition of vitriolic acid, immediately forms a snowy white vitriol, which washed, collected, and dried, may be supposed to weigh a, in which case the corresponding lead is $= \frac{100a}{143}$. The liquor remaining after the precipitation yields, by evaporation to dryness, a phosphoric acid.

The colour, both of this and the former ore, is owing to iron; generally they are green, sometimes yellow, but rarely red; they occur white, and sometimes pellucid; and all affect a crystalline, especially a prismatic form.

§ VIII. *Ores of Copper.*

Copper, besides its metallic form, assumes a variety of shapes: it is generally united with sulphur, and very seldom without iron; but it also sometimes occurs mineralized by aerial, vitriolic, and even by marine acid.

(A) Native copper readily dissolves in nitrous acid; if gold be present, it falls, untouched, to the bottom, in form of a

F f 2

black

black powder; if silver, it is soon precipitated by copper; if iron, by boiling the solution for some time, and inspissating to dryness, it is gradually calcined, and separates.

(B) When mineralized by sulphur, let it be powdered and gently boiled to dryness in five times its weight of concentrated vitriolic acid; let the residuum be well washed with water, until all the metallic part has entered the menstruum.

The solution requires at least a portion of water equal to four times the vitriol which is to be dissolved, and therefore the quantity should be adapted in some degree to the goodness of the ore: that which contains 0,05 of copper requires about 0,8 of water, and so on. Let a polished iron plate, about twice the weight of the copper, be immersed in the solution properly diluted; let boiling be continued until no further precipitate is occasioned. If the quantity of water be too small, the precipitated metal adheres very pertinaciously to the iron plate, which, by a proper quantity, is always completely freed. Let the precipitated copper, well washed, be speedily dried; but yet with such a degree of heat as to make the surface of the metal of different colours, which instantly and sensibly increases the weight.

If the precipitated copper be found mixed with iron, which is sometimes the case, especially

especially in the examination of a poor ore, this must be again dissolved, to obtain a richer solution; which deposits pure copper, if the operation be conducted as above described. The same circumstance takes place in the precipitation of silver by copper; a rich solution yields the metal pure, but a poor one yields it alloyed with copper.

If the copper to be precipitated contains other metals, these may easily be separated by solution in the nitrous acid. Gold remains at the bottom, undissolved, in the form of a black powder; and silver precipitates upon a copper plate.

During this process, the whole, or a great part of the sulphur, flies off by the intense heat necessary for evaporating the vitriolic acid to dryness; yet its quantity may in some degree be judged from the sum of the weights of the other ingredients, compared with the weight of the whole; besides, if thought necessary, a solution in aqua regia may be made for the purpose of collecting the sulphur.

(c) Copper, mineralized by aerial acid, is of an elegant green colour, and is commonly called malachites; to this also belongs the green filken ore of copper, which is of the same nature. These ores, when pure, are totally soluble in acids, and may be precipitated either by iron or aerated alkali. In the latter case, supposing the weight

of the precipitate to be $= a$, the metallie copper contained will be $\frac{100a}{194}$ (i).

If calcareous earth be mixed, which sometimes happens, this may be thrown down by aerated alkali, after the precipitation of the metal by phlogisticated alkali.

Calciform blue copper consists also of copper mineralized by aerial acid. Its principles are discovered in the same way.

Calciform red copper, or of a brownish red, is called by Mr. Cronstedt the glassy ore of copper. This also is totally, or for the most part, dissolved, and that with an effervescence, though somewhat weaker than the other; so that it is doubtful whether any calciform ore of copper is entirely destitute of aerial acid. I have not seen the red pelucid ore lately discovered and described by Mr. Sage.

I have examined in many different ways the red quartz, which is supposed by Mr. Cronstedt (k) to contain such a calx. The

(i) The illustrious Fontana was the first who determined the true nature of the malachites. He found that it contains $\frac{2}{3}$ of calcined copper, $\frac{1}{4}$ of aerial acid, and about $\frac{1}{10}$ of water. The same principles he discovered in the green filken ore, their proportions only being somewhat varied. This obtains also with respect to the blue ore; but in this the aerial acid forms a larger part of the whole, amounting nearly to $\frac{1}{3}$ or $\frac{1}{2}$; on the other hand, in the specimens which have been examined, the proportion of the water is diminished by $\frac{1}{12}$ to $\frac{1}{37}$.

(k) Mineralog. § 196. b. 2.

volatile alkali did not extract any copper, nor did the vitriolic acid, though abstracted to dryness. As the siliceous matrixes hardly admit the menstrua, I added a portion of the mineral fluor to the vitriolic acid; for the fluor acid, when expelled, attacks the quartose particles, so as to set at liberty even the last portions of copper; but although this experiment always succeeds when copper is present, yet in the instance of this ore not the smallest sign of that metal could be discovered; and therefore it is not without reason that we doubt of its presence.

(D) Copper, mineralized by vitriolic acid, is no other than the common blue vitriol, which sometimes occurs native. The copper it contains is easily precipitated by iron in the manner above described.

(E) In the collection of the Academy of Upsal there occurs a specimen of a dilute greenish red, friable, and of small specific gravity, which dissolves with effervescence in nitrous acid, imparting a green colour to the menstruum. Upon the addition of iron the copper is precipitated; and upon dropping in a solution of silver, a white coagulum is separated, being a genuine faltered silver; so that no doubt can be entertained of the presence of marine acid, an opinion which is also established by the *via sicca* in many ways, which I here pass over.

We find vestiges of the same acid in the beautiful green ore of Saxony, which is cubic or squamous, and has been referred to the species of mica or talc. I have lately, by favour of Mr. Werner, had an opportunity of examining a specimen interspersed as it were with this substance. It dissolves totally in nitrous acid, and acquires a green colour; the copper is discovered by many precipitants, as by iron, by volatile and phlogisticated alkali; but the marine acid is discovered with far more difficulty; yet upon dropping in a solution of silver, a true luna cornea falls, but in small quantity; there appears a portion of green scales, which did not weigh one grain; the smallness of the quantity prevented me from making any further experiment; but those already made put it beyond doubt that this deserves a place among the ores of copper; it contains also a little clay, but the quantity remains to be determined by experiment on larger quantities.

§ IX. *Ores of Iron.*

Traces of this most common of all metals are found almost every where in the mineral kingdom; yet the ores which contain it in considerable quantity present it either mineralized by sulphur, or more or less calcined: it is rarely found united with vitriolic

vitriolic acid; and very seldom in a complete metallic form.

(A) Mineralogists are not yet agreed whether iron be found native. Concerning that of Siberia, a dispute is still carrying on; and indeed it cannot be denied, but that the cavities in the iron mass shew it to have been fused, and as it were inflated by spumescence; yet many circumstances seem to indicate, that if this operation ever took place, it was performed without the assistance of art. The stoney matter which fills all the cavities is of a very different nature from the scoriæ produced in our furnaces. To pass over its situation, and other circumstances, the iron itself, when cold, or moderately warm, is found to be very tenacious and malleable; but when made red hot becomes brittle, but exhibits altogether the same phænomena, when examined by the *via sicca*, as forged iron; with marine acid it diffuses an hepatic odour, which evidently shews the presence of sulphur, phlogiston, and the matter of heat, as without these no such smell ever arises. It is probable that the matter of heat is taken from the fire by the metals in fusion; yet we cannot therefore certainly conclude, that every thing which contains the matter of heat has been exposed to fire: and supposing that the Siberian iron has undergone fusion, it cannot from thence be inferred, that this has been occasioned by art. But
this

this very rare mineral deserves to be separately and particularly examined.

Ores of iron are frequently found in Sweden so perfect as to be obedient to the magnet, nay, sometimes are themselves magnetic; but these, both with respect to menstrua and other properties, differ from iron eliquated by fire. Such iron as may properly be called native may yet be brittle; for that which is extracted artificially, and is malleable, easily contracts brittleness, but must with menstrua preserve the same habits as the forged.

(B) The attractive and magnetic ores, though they do not contain much sulphur, yet are seldom entirely without it; but none of it could be extracted by menstrua.

Such as are saturated with sulphur, are called sulphureous pyrites, as nothing but sulphur is extracted from these; for although they sometimes contain enough of the metal to pay the expence of eliquation, yet the metal extracted by its brittleness is rendered intractable in the fire; and, exposed to the open air, easily falls into a rust.

(c) Iron, mineralized by vitriolic acid, is produced daily by the spontaneous decomposition of pyrites, which is again gradually so dephlogisticated as at length to lose all connection with the acid. These vitriolic reliquiae, washed away and deposited in lower situations, perhaps generate the ores of lakes and marshes.

(D) The

(D) The hæmatites yield a calx of iron under various forms, of an iron colour, a red, a black, or a yellow. Other ores also contain it, but of a lax and powdery texture, generally mixed with other earths.

Whether any of these ores contain iron naturally mineralized by aerial acid in the bosom of the earth, is yet unknown. Artificially, this subtile acid is greedily taken up; but all the natural calxes of iron hitherto examined shew no signs of it, except the white ores of iron; but as these contain aerated manganese and calcareous earth, it is doubtful whether the martial particles contribute to furnish any of the aerial acid extricable from these ores.

(E) All the ores of iron, reduced to a very subtile powder, and repeatedly boiled in marine acid, yield up the metal. If the pyrites are more slowly dissolved, the addition of a small quantity of nitrous acid accelerates the operation.

The iron being extracted, the matrix, if insoluble, remains. Now, in order to obtain the metal alone, let it be all separated by phlogisticated alkali. Suppose the precipitate, when washed and dried, = a , then the corresponding quantity of metallic iron will be $\frac{a}{6}$; but this formula must be corrected according to the quantity of the precipitant, as before observed (§ II.).

That which is of itself soluble by means of

of vitriolic acid, requires nothing but water to precipitate by phlogisticated alkali.

Manganese is frequently united with iron, and is discovered without difficulty by immersing the blue sediment (carefully weighed) in water sharpened by nitrous acid, by which the part arising from the manganese is dissolved, as we shall see hereafter (§ XVII.). Other methods of effecting this are described elsewhere (1).

Besides this metal, there are others which enter the ores of iron in still larger quantities, which for the most part render the ores useless, by imparting noxious qualities to the eliquated iron.—We shall speak of zinc, &c. and of the manner in which they are to be separated, in their proper places.

§ x. *Ores of Tin.*

Many testimonies concur in asserting that tin is found native in England; but I have never met with any specimen of it.

But the ores of tin almost always preserve the same crystalline nature, although the grains are often found so subtilely dispersed in different matrixes as entirely to elude the sight. I have lately obtained a peculiar variety found in England, which,

(1) Essay on the White Ores of Iron, § VIII.

consisting

consisting of contiguous sphaerical strata, and radii proceeding from a center, very much resembles the brown hæmatites. In all these tin is present, simply calciform, and involved in siliceous particles; and, so far as is yet known, never mineralized, either by marine or aerial acid, or by sulphur. The absence of the latter is the more extraordinary, as this mineralizing substance is produced by nature in great quantities, and is artificially united to tin with great ease.

(A) The examination of tin by the humid method is attended with no difficulty; for the addition of nitrous acid quickly deprives it so far of its phlogiston, as to reduce it all to a white calx; the iron and copper, if any be present, remaining in the liquor. 100 parts of tin, corroded by nitrous acid, washed and dried, yield 140 of white calx: arsenic may be separated by washing the calx with large quantities of warm water; for but little enters the acid menstruum. The other metals are but rarely united with truly native tin.

(B) The pure ore is commonly called, according to the magnitude of its crystals, *zinngraussen*, or *zwitter*. The examination of these forms is the great difficulty of the humid method, as they are not acted upon effectually either by vitriolic, nitrous, or marine acid, or by aqua regia.

The reason of this pertinacity is, that the calx, being well dephlogisticated, is either
not

not taken up at all, or very sparingly, and is besides involved in stoney particles, which elude the action of the acids. The method by which this process seems to be most nearly effected, is as follows :—

To a very subtile powder of this ore, obtained not only by levigation but elutriation, let there be added a quantity of concentrated vitriolic acid, and let this be exposed to a strong digesting heat for several hours ; then let there be poured on a small portion of concentrated marine acid, and upon agitating it a vehement effervescence immediately begins with considerable heat, arising from the marine acid, which is partly deprived of its water by the vitriolic, and generates a marine acid air : by this method the forces of the two acids are conjoined. After the space of about an hour, let water be added, and upon subsiding the clear liquor decanted. This operation is to be repeated with the residuum, until the acids can dissolve no more.

What remains finally undissolved, is nothing more than the stoney matrix.

Let the solution, precipitated by means of aerated alkali = a , and the quantity of regulus sought will be $\frac{1300}{131} a$.

The subtile atoms of the crystalline ore, intimately mixed with any matrix, may, after due pulverization, be separated by washing from a given portion, as the crystals are nearly of six times greater specific gravity

gravity than water; so that they not only exceed the earthy particles, but the ores of other metals, and approach even to the lighter metals themselves. The crystalline particles, after being separated, are exposed to the trial above-described, the larger distinct crystals can seldom be employed; the most common ore contains particles of them very much dispersed.

The adventitious metals usually found in ores of tin, are copper and iron.

§ XI. *Ores of Bismuth.*

Bismuth, which is the most ponderous of the semi-metals, occurs partly native, partly mineralized by sulphur, and sometimes perhaps even by the aerial acid. Some deny that this metal is found naturally united with sulphur, but without foundation; for although such has not yet been found in Germany, it is undoubtedly obtained in many mountains of Sweden, especially at Ridderhyttan in Westmania. Calciform bismuth is of a white colour, but it rarely occurs; so that it cannot yet be certainly determined whether it be mineralized by aerial acid or not.

(A) Native bismuth is easily taken up by nitrous acid, and may then be precipitated by water; which done, if any other metals are mixed with it, they remain in the liquor, and

and may be separated as above-described in various places.

(B) When mineralized by sulphur, it is decomposed by slight boiling in the same menstruum; so that the sulphur may be at last obtained, which when washed and collected, is to be examined as to its purity and quantity.

The solution of the metallic part, precipitated by water, yields a white calx; let its weight = a , and that of the corresponding metal will be $\frac{100a}{113}$.

In these mineralizations iron is sometimes found, which, after the separation of the bismuth, is easily discoverable.

(c) Calciform bismuth, whether alone, or mineralized by aerial acid, also enters the nitrous acid, and may be precipitated by water, upon which the heterogeneous matters remain in the liquor. The presence of cobalt is discoverable immediately, by its communicating a red colour.

§ XII. *Ores of Nickel.*

Nickel is found, but very sparingly, mixed with other matters, yet it appears under a variety of forms; sometimes native, or united with a little sulphur, yet at the same time intimately united with iron, cobalt, and arsenic; so that these adventitious metals cannot be separated without much difficulty,

difficulty, and the iron hitherto but imperfectly; but it occurs mineralized by the vitriolic, and possibly by the aerial acid.

(A) Native nickel is taken up by nitrous acid, and when precipitated by aerated alkali, yields a calx which almost always contains iron, arsenic, and cobalt, in the same proportions in which they generally accompany the regulus eliquated in the usual way: if silver and bismuth happen to be also present, which yet is very rarely the case, the former is to be precipitated by muria before the alkali is employed.

(B) If sulphur be present, it may be separated and collected during solution.

(C) Nickel, mineralized by vitriolic acid, is scarcely ever without iron; a great part of the martial inquinament is separated by long and violent boiling in water. Aerated alkali throws down a greenish white precipitate: let the weight of this = a , and the common reguline nickel is = $\frac{100 \cdot a}{135}$.

(D) The same metal, mineralized by aerial acid, is dissolved by the nitrous acid, and precipitated by means of aerated alkali.

A more compleat account of the examination of this metal, may be found in a preceding treatise.

§ XIII. *Ores of Arsenic.*

Arsenic is produced by nature, both reguline, mineralized by sulphur, and calcliform.

(A) If the purity of native arsenic is to be examined, let it be dissolved in four times its weight of aqua regia, and the solution slowly evaporated, without any separation of the metal; after this, let the arsenic be precipitated by water, and collected upon a filter; the clear liquor which passes through will contain the heterogeneous metals: if any silver be present, it seizes the marine acid, and falls to the bottom.

Iron is scarce ever entirely absent, and is frequently in such quantity that the mass appears polished, most commonly crystalline, and is vulgarly known by the name of misspickel, which is with justice considered as belonging to native arsenic, as it neither contains any sulphur, nor any mineralizing acid. It must indeed be confessed, that arsenic itself is nothing more than a peculiar acid coagulated by phlogiston, in a manner similar to sulphur; but the same thing is perhaps true of all the metals; and besides, the acid of arsenic, when loaded with phlogiston, puts off its acid nature, and therefore in that case cannot be looked upon as a mineralizing substance; but if at any time
it

it shall be found in the bosom of the earth, united in the manner of an acid menstruum to any metal, it then beyond doubt is to be considered as a mineralizing substance.

(B) Let arsenic, mineralized by sulphur, be dissolved in marine acid, with the addition of the nitrous occasionally, in greater or lesser quantity, so that the sulphur may be separated free from all the metallic matter. The sulphur collected, washed, and weighed, indicates the quantity of the arsenical part; this however ought to be precipitated separately by water, and weighed, a step which is necessary wherever great accuracy is required. Sallited arsenic may also be precipitated in its metallic form, by zinc, the solution being previously weakened by spirit of wine.

When sulphur alone is united to the arsenic, by its different proportions it produces different colours, from a dilute yellow to an intense red; but if a considerable portion of iron also enters the composition, a white colour is generated, and a very different species of pyrites formed, which is called the arsenical pyrites: the metallic principles of this, dissolved in marine acid, or aqua regia, may be separated in the manner above described.

(c) Calciform arsenic, which nature seldom produces, is dissolved and examined by means of marine acid.

In general, concerning arsenical ores, we must guard against using too much nitrous acid, as by that the whole of the phlogiston is readily taken away, and the acid disengaged: the smallest quantity therefore which is sufficient for solution should be employed, otherwise water will occasion no precipitation; and, notwithstanding all our caution, it is scarce possible to prevent the disengagement of a portion of the arsenical acid, especially if the boiling be long continued; this may be recovered by evaporating to dryness, yet rarely alone, but occasionally, and according to the laws of attraction, united either with the alkaline earths, or the metals which are present (*m*). Some of the arsenic easily flies off.

§ XIV. *Ores of Cobalt.*

Reguline cobalt often occurs totally destitute both of sulphur and acids, that is,

(*m*) Regulus of arsenic may be very commodiously obtained in the following way, by the *via sicca*:—white arsenic, with three times its weight of black flux, is put into a crucible, which is covered by another, and luted so closely that the access of external air is altogether prevented. This being done, the lower crucible is gradually exposed to a red heat, and in the mean time the upper crucible is protected from the effects of the fire by means of a copper plate; by this method, the inner surface of the upper crucible is covered with a polished, crystallized, reguline crust, which may in general be separated whole by a gentle concussion.

native,

native, and only mixed with other metals; it is also found united with sulphur, and mineralized by the acids of vitriol and arsenic. Nature moreover exhibits a black calx of cobalt: it is not yet certainly known whether it is ever loaded with the aerial acid.

(A) When native, it almost always contains iron and arsenic, and often nickel; and hence no doubt it is, that some authors assert that vitriolated cobalt, and the other salts containing this metal, are of a green colour; whereas they really are of an obscure red, unless the nickel be in large quantity. In order to separate these metals, let the mixture, dissolved in aqua regia, evaporate to dryness, and let the cobalt be extracted by vinegar; suppose this, precipitated by aerated alkali, be in weight = a , then the corresponding quantity of regulus = $\frac{100a}{160}$. We have already treated of the nickel and the iron (§ XII.) ; if the arsenic be superabundant in the evaporated solution, it may perhaps be precipitated by water.

(B) Cobalt united with sulphur may be treated in the same way, as it differs from the native cobalt only in containing a small quantity of sulphur, which is to be separated and collected.

(C) The celebrated Mr. Brandt has discovered Cobalt joined to vitriolic acid, with a large quantity of iron, and without any arsenic. This I have examined in the hu-

mid way, by solution in aqua regia. The yellow solution, on account of abundant iron, was scarce red, but by boiling assumed an obscure green, and upon cooling recovered its former colour; a property which distinguishes cobalt. No sulphur could be collected; but a few drops of salited terra ponderosa, dissolved in water, immediately discovered the vitriolic acid. Scarce any arsenic appeared.

If in this instance the vitriolic acid be present in a dephlogisticated state, as appears to be the case (unless we rather chuse to suppose that a very few particles of sulphur have been dephlogisticated during the solution) yet this acid is not present in such quantity as to give birth to a vitriolated cobalt; for the mass is of a metallic nature, and therefore the acid is to be considered only as an inquinament.

The trichites of the Greeks, which is found in the mines of Herngrund and Idria, adhering to an argillaceous stone, is found to contain somewhat of a real cobalt, besides the clay and vitriolic acid; this can be precipitated only by a phlogisticated alkali.

(D) Cobalt frequently exhibits beautiful red efflorescences, of a colour sometimes more dilute, sometimes more saturated; it appears now like a loose powder, now concrete; nay at times it forms most beautiful crystals, radiating from the same center in the

the manner of a star. These substances always shew some vestiges of arsenic; but neither reguline nor white arsenic are capable of imparting the red colour to cobalt; this can only be effected by acids. Since therefore the colour indicates the presence of an acid, it is reasonable to conclude it to be the arsenical acid. The white arsenic, which is almost always adhering to the ores of cobalt, may perhaps be sometimes so much dephlogisticated by time, that the acid, being extricated, is in a condition to act upon the contiguous particles of cobalt.

In order either to establish or to overthrow this suspicion, I thought it proper to consult experiments. I found an exact correspondence to subsist between cobalt, artificially saturated with acid of arsenic, and the natural red crystals of cobalt, except that the latter sometimes contained white arsenic. The arsenicated cobalt is not taken up by water, unless the acid be superabundant; and this it is, perhaps, which prevents the separation of arsenicated lime, upon the addition of salited lime to the solution; however, the event of the experiment is the same, whether the arsenicated cobalt employed be natural or artificial;—on evaporating to dryness an arsenicated lime appears.

On account of the scarcity of this substance, I instituted another experiment in small:—I extracted the pure acid of arsenic, first separating it by vitriolic acid, and then

absorbing it by highly-rectified spirit of wine; for this last does not take up the vitriolated cobalt, but only the disengaged acid.

Natural arsenicated cobalt is scarcely soluble in water, unless the water be sharpened by an acid, and when thus dissolved it should be precipitated by aerated alkali, to discover the quantity of reguline cobalt. Cobalt, artificially arsenicated and sufficiently dried, shews the same properties as the natural.

(E) I have sometimes examined earths more or less compact, green or blue, which appear to contain a little cobalt; but in these specimens copper abounded, more especially in the blue, which also effervesce violently in acids. Let the copper be first precipitated from the solution by iron, the liquor evaporated to dryness, and the cobalt dissolved by vinegar; if any of the iron adheres to the vinegar it separates on boiling.

(F) The black calx of cobalt is generally found concreted into an hard mass, known by the name of glassy ore of cobalt; this, when pulverized, is taken up by aqua regia or marine acid, and may be examined like the former. I have not certainly discovered in these the aerial acid.

§ xv. *Ores of Zinc.*

Many still doubt whether zinc be ever found native; it is seen mineralized by sulphur

phur in the pseudo galena; by vitriolic acid, in native white vitriol; and by aerial acid, in lapis calaminaris, and in the other ores which are called glassy.

(A) If at any time native reguline zinc, without any artificial assistance, be found, its purity may be easily examined, as it is quickly dissolved in all the common mineral acids, and whatever heterogeneous metal is present may be precipitated by zinc. The factitious white vitriol rarely contains any other metal, except lead.

(B) The pseudo galena, which contains zinc mineralized by sulphur, together with iron, must be carefully treated with nitrous acid, in order to extract the metallic part without injury to the sulphur: if no other metal than iron be present, let it be precipitated by zinc; but if more, the iron must be calcined by repeatedly abstracting nitrous acid to dryness, and the new solution, made by vinegar or any other menstruum, examined.

Hepatic air is generated by the vitriolic, and still more copiously by the marine acid; but as this elastic fluid consumes a part of the sulphur, I have rather directed the employment of nitrous acid with caution in the solution of pseudo galena.

(c) Let the zinc, united with vitriolic acid, be dissolved in water, and precipitated by an aerated alkali; let the weight of aerated

aerated be a , and that of the reguline metal zinc is $\frac{100a}{193}$.

If, as is generally the case, iron be present, this should be precipitated by a known weight of zinc.

(D) Zinc, mineralized by aerial acid, and dissolved in acids, should be precipitated either by aerated or phlogisticated alkali; in the latter case, or in order to determine the metallic part, the weight of the sediment must be divided by 5.

In the Treatise on Zinc we have described at large how the matrix and other heterogeneous matters are to be separated on different occasions.

A zinc, mineralized by spar, has lately been discovered (n); and I hope, by favour of the illustrious discoverer, that it will be soon examined by the humid way, as the mineralizing substance (o) is hitherto unknown.

§ XVI. Ores of Antimony.

Stibium, commonly called *antimony*, has as yet been met with only under two diffe-

(n) By Mr. Von Born.

(o) It is always extremely difficult to extract zinc from its ores in the *via sicca*. The ore roasted with charcoal-dust in the way described in note (m), it is true, yields several particles of zinc in the upper crucible, especially if that crucible be perforated by an hole, and covered above by another, well luted on; but hitherto it has been found impracticable to sublime more than one half of the contents of the lower crucible.

rent

rent forms, namely native, or mineralized by sulphur.

(A) Mr. Suab, in 1748, first discovered native antimony in a calcareous matrix at Sahlberget, nor do I know that it has been found any where else, however, in the collection of the Academy, there is a small piece found somewhere out of Sweden, but where is uncertain; this is in a quartose matrix: so that it appears native antimony is found in other places, though rarely, and though little known in this country.

The purity of the metal is most conveniently examined by reducing it to a calx with strong nitrous acid; for this being done, if it be entirely pure, there will remain dissolved in the menstruum only a small part, which separates upon the addition of water.

(B) The metallic part of antimony, mineralized by sulphur, is taken up by aqua regia, and the sulphur remains pure. The solution, mixed with strong nitrous acid, on boiling deposits a calcined antimony, which being separated, the remaining liquor may be examined by phlogisticated alkali, or any other means.

Sulphurated antimony, by a certain quantity of arsenic, grows red, frequently exhibiting beautiful fasciculi of filaments radiating from a center. If arsenic be present it is thus discovered:—let the powder be gently boiled in aqua regia until the sulphur is obtained

obtained pure; the clear solution contains the antimony and arsenic, which are separated in the following manner:—let concentrated nitrous acid be poured on, and the antimony reduced to a white calx by boiling; let this be collected on a filter, and the liquor that passes by evaporation yields the arsenic, generally spoiled of phlogiston, that is, the arsenical acid.

Besides, as the caustic alkali takes up both sulphur and antimony, this, aided by heat, may be advantageously employed, especially for the separation of silver or other metals which do not yield to this menstruum; an hepar is indeed generated, but in this instance it dissolves little or nothing.

§ XVII. *Ores of Manganese.*

The newly-discovered semi-metal, manganese, accompanies most ores of iron, as has been before observed (§ III, c). It has however ores of its own, in which it predominates, though they are seldom to be found; it has no where yet been observed native, nor mineralized by sulphur, unless when joined with other metals in larger quantities; it commonly occurs calciform, but under various forms; generally alone and black, sometimes mineralized by aerial acid.

(A) Calciform manganese alone generally possesses a metallic splendor, is partly of an

an earthy colour, black or red: the colours are no doubt owing to unequal portions of phlogiston.

Let these ores, reduced to a subtile powder, be immersed in any, but particularly a mineral acid, together with a small piece of sugar. It is known that the calx of this metal eludes the force of acids, unless somewhat be added to supply the necessary quantity of phlogiston. Let fresh acid be repeatedly poured on with sugar, until no more is extracted by a digesting heat; let the solution collected be precipitated by aerated alkali; let the weight of the sediment be a , and the corresponding regulus will = $\frac{100a}{130}$.

What remains undissolved at the bottom either belongs to the matrix, or contains heterogeneous mixtures.

(B) Aerated manganese is rarely found pure but in the gold mine at Nagyay: when it forms the matrix, it is had scarcely mixed with iron; at least, in a solution made with nitrous acid, the phlogisticated alkali does not discover it. In general the iron is in larger quantity, as in the white ores of iron; but these ores are to be treated as before described.

In order to separate the iron when it abounds, or at least the greatest part of it, let nitrous acid be repeatedly abstracted to ignition from the ore; after which the manganese pure, or at least not much contaminat-

ed by iron, may be separated by strong concentrated vinegar, or diluted nitrous acid.

Manganese, precipitated from superabundant nitrous acid, by phlogisticated alkali, dissolves totally in distilled water; a property which affords a method of separating it from iron.

We cannot positively assert whether manganese, joined to marine acid, is ever found in the bosom of the earth; although it seems probable, on the supposition that natural waters are sometimes found loaded with salited manganese (*p*).

Thus we have mentioned the fifteen metals which are known to be distinct, and have pointed out processes by which the chief varieties of their ores may be examined in the humid way: the greater numbers of ways by which these bodies can be examined the better; now one method is necessary, now another. But I have no doubt that multiplied experiments will discover methods more numerous and effective than those proposed in the foregoing sketch.

(*p*) The celebrated P. J. Hjelm discovered waters of this sort about the lake Vettern.—Compare Mr. Scheele's *Chemical Prælections*, § 189. Obs. 3.

DISSER-

DISSERTATION XXV.

OF THE
BLOW-PIPE;

And its Use in the Examination of
Bodies, particularly Minerals.

§ 1. *Introduction.*

THE tube which, from the uses to which it has been applied, is called the folding tube, or blow-pipe, is very useful and necessary to many artificers; but our countryman, the celebrated metallurgist Andreas Swab, was, if I mistake not, the first who applied it to the examination of minerals, and that about the year 1738. This invention was afterwards much improved by
Messrs.

Messrs. Cronstedt, Rinman, Engestroem, Quist, Gahn, and Scheele; nay, Mr. Engestroem has written an express treatise upon its uses, which was first published in English, afterwards translated into the Swedish, and finally the German language. The experience of many years has however shewn me, that this instrument is susceptible of further improvement, both as to construction and application: I shall therefore relate such circumstances concerning it as may be comprized in a brief description.

§ II. *Figure of the Instrument.*

That which I use is formed of pure silver, lest it should be injured by rust; a small addition of platina communicates the necessary hardness.

It consists of three parts, which may occasionally be joined: an handle A (tab. 2), terminating in a truncated conical apex a a, which may be, by twisting, so adapted to the aperture b as to shut it more closely than can be done by a screw. In the place of the hollow sphere which is commonly used, I make use of the little box B, formed of an elliptical plate, so bended through the centre that the opposite sides become parallel, and are joined round by a plate equal in breadth to c c: such a box collects the moisture of the breath as well as the sphere,
and

and is besides attended with the advantage of a compressed figure, and smaller circumference. The aperture (b) is somewhat conical, and hollowed out of the solid piece, and has no margin turned inwards, lest the efflux of the fluid, collected after long blowing, or the cleansing of the internal parts, should be in any degree prevented. The tube (c) is very small, and its shorter conical end (e'e) exactly fitted to the aperture (f), so that no air can escape, unless through the orifice (g). Many of these tubes should be provided, with orifices of different diameters, to be applied on different occasions; the orifice (g) itself ought to be smooth and circular, otherwise the cone of flame, hereafter mentioned, will be divided (§ III.). The bands (h h, i i) prevent the conical apices (a a, e e) from being thrust in too far, and also serve another purpose; for when the conical apices (a a, e e), by repeated attrition, are at last so much diminished as to fall out spontaneously, by filing away a little of the bands, they may again be made tight. The figure represents the whole apparatus of the proper size.

§ III. *Method of blowing through the Tube.*

As it is absolutely necessary that the air should flow through the orifice in a continued stream, so long as the experiment

VOL. II.

H h

continues

continues to require it, this labour will fatigue the lungs too much, unless an equal and uninterrupted inspiration can at the same time be continued. To succeed in this operation without inconvenience, some labour and practice are necessary. The whole artifice, however, consists in this, that while the air is inspired through the nostrils, that which is contained in the mouth be forced out through the tube by the compression of the cheeks.

To some persons this is extremely difficult; but frequent trials will establish the habit, so that a continual stream of air can be supplied for a quarter of an hour and more, without any other inconvenience than the lassitude of the lips compressing the tube.

§ IV. *The proper Kind of Flame.*

The stream of air above mentioned is necessary for impelling the flame upon the matter under examination. Too great a flame does not easily yield to the blast; and too small a one produces a proportionably weak effect: a slender candle should therefore be chosen (either wax or tallow) (d) with a cotton wick (k l). The burned top must be cut off at such a length that the remainder may be bent a little (l m). The orifice (g) is to be held above, and near to this arch, perpendicular to (l m); and the air equably expressed.

The

The flame being forced to one side by the violence of the blast, exhibits two distinct figures; the internal figure (l n), conical, blue, and well defined; at the apex of this (n), the most violent degree of heat is excited; the external (l o), brownish, vague, and undetermined, which is spoiled of its phlogiston by the surrounding atmospheric air, and occasions much less heat at its extremity (o) than the interior flame does.

§ v. *Proper Supports for the Matter under Examination.*

The substances to be examined, are supported by two different sustentacula, according to the diversity of the matters under consideration; the one is charcoal of beech or fir, cut into the form of a parallelopiped; the other a silver, or (which is better) a golden spoon, fitted with a wooden handle. The first of these is generally used, except where phlogiston is to be avoided, or the subject under examination is absorbed by charcoal. The golden spoon should be much less than the figure (E), as the bulk of the support impedes the proper heat of the matter exposed to examination.

Particles that are very small and light are easily carried off by the blast of air; to prevent which a small cavity should be hollowed out in the charcoal, in which, be-

ing partly protected by another smaller piece of charcoal, they may be exposed to the apex of the flame.

§ VI. *Proper Fluxes.*

Substances which are not fusible *per se*, are often fused and dissolved by means of salts; I make use of three in particular, one of which is acid, another alkaline, and the third neutral.

1. The phosphoric acid, or rather the microcosmic salt, as it is generally called, which contains that acid partly saturated with mineral, partly with volatile alkali, and loaded besides with much water, and a gelatinous fat. This salt, when exposed to the flame, boils and foams violently, with a continual crackling noise, until the water and volatile alkali have flown off; afterwards it is less agitated, sending forth somewhat like black scoriæ, arising from the burned gelatinous part; these are soon dispelled, and exhibit a pellucid sphærule, encompassed by a beautiful green cloud, which is occasioned by the deflagration of the phosphorus arising from the extrication of the acid by means of the inflammable matter.

The clear globule which remains, upon the removal of the flame continues longer soft than that formed by borax, and therefore is more fit for the addition of the mat-

ter

ter to be dissolved. The volatile alkali is expelled by the fire, therefore an excess of acid arises in what remains, which easily attracts moisture in a cool place.

2. The mineral alkali, or sal sodæ, which, when fused upon charcoal, melts superficially, with a crackling noise, penetrates the charcoal, and disappears: this, in the spoon, yields a permanent and transparent sphærule, so long as it is kept fluid by the blue apex (n); but when the heat is diminished puts on a milky opacity; hence it appears why this cannot be employed upon charcoal. This alkali attacks several substances, particularly siliceous matters.

3. Crystallized borax, exposed to the flame upon charcoal, at first becomes opaque, white, and wonderfully intumescent; it throws out branches and various protuberances; but when the water is expelled, it is easily collected into a mass, which, when well fused, yields a colourless sphærule, which retains its transparency even after cooling: if calcined borax be employed, the clear sphærule is more speedily obtained. This salt consists of mineral alkali partially saturated with a peculiar acid, known by the name of sedative salt; each of its principles is separately fusible, and each dissolves a great number of other matters.

The habits of these salts, when exposed to fire, being once known, it will be easy

to understand the differences occasioned by the different additions.

§ VII. *Circumstances to be observed in the Examination of Bodies by the Blow-pipe.*

The exterior flame must first be directed upon the mass under examination; and when its efficacy is well known, then the interior blue flame.

Particular care must be taken to observe whether the matter decrepitates, splits, swells, liquefies, boils, vegetates, changes colour, smokes, is inflamed, becomes oily, or magnetic, &c.

The piece exposed to the flame should scarcely ever exceed the bulk of a grain of pepper; but ought never to be so small as not be taken up by the forceps (I); as, if it be too large, a part of it is necessarily without the focus, and must cool both the support and the part immersed in the blue apex. The particles may be sufficiently comminuted upon the steel plate (G) by the hammer (F), and are prevented from being dispersed by the ring (H).

A small piece should be added separately to each of the fluxes, concerning which it must be observed, whether it dissolves wholly, or in part only; whether this be effected with or without effervescence; quick-

ly or slowly; whether the mass be divided into a powder, or gradually and externally corroded; what colour the glass is tinged; whether it be opaque or pellucid.

These general principles shall now be applied to exemplify the mineralogical and chemical use of the blow-pipe.

§ VIII. *Four Classes of Fossils.*

Unorganized bodies are generally distributed into four classes; saline, earthy, inflammable, and metallic.

The salts are distinguished by solubility and sapor: but these properties differ in many ways as to degree, and in fact form a continued series with the earths; so that the links in the chain of nature can scarcely be distinguished, unless artificial limits be instituted.

Many of these, when exposed to the flame, easily liquefy, or are dissolved by the water of crystallization growing hot; but when this is expelled, split, and, by a more intense heat, are really fused: others are deprived of their water without any motion, and are only once fusible: some fly off by the heat.

Earths I call such substances as are fixed in the fire, not sapid, nor, though reduced to the most subtile powder, soluble in 1,000 times their weight of boiling water. Some

of these, either by having their surfaces increased by a previous chemical division, and their surface of contact thereby increased, or by the assistance of an excess of aerial acid, or by exposure to intense heat in close vessels, actually are dissolved in water; these I call saline earths: but the rest, which can, by no artifice hitherto known, be made to enter water, deserve the name of earths simply, and κατ' ἐξοχην. Examined by the blow-pipe *per se*, they are found either refractory or fusible; and very few of them alone exhibit a transparent glass. They are dissolved by the abovementioned fluxes, or at least by one of them; besides, they neither burn nor smoke.

Most of the inflammable substances burn, smoke, and yield coals loaded with an oily matter. Sulphureous bodies burn without any residuum; but some of these are only manifested by volatility.

The metals, excepting a few, are fusible; the ignoble metals are calcined, and colour the fluxes.

§ IX. *Different Species of Salts.*

The salts, whether natural or factitious, are very easily examined by the blow-pipe. Some of these are properly called salts, consisting entirely of a soluble matter; such are acids, alkalis, and the neutrals composed

of these; but the others, containing a base not soluble *per se*, either earthy or metallic (which is not soluble in water, unless when united with a genuine salt) may be called middle or analogical salts.

§ x. *Acids.*

The acids which are always fluid I pass over, as they elude the flame, and shall here only examine the concrete salts.

The acid of arsenic must be carefully distinguished from white arsenic, which contains this acid indeed, but unites with so much phlogiston, that it is coagulated (*a*) into a sort of sulphur. This acid, deprived of water, exhibits a dry mass; and, exposed in this state to flame upon charcoal, receives from thence so much phlogiston, as to regenerate white arsenic, and diffuse a garlic odour. In the spoon it fuses, and does not smoke, unless by the acquisition of phlogiston, either from the flame or the metallic support.

The acid, which exists molybdæna (*b*), seems to be the radix of some metal; it is of a specific gravity 3,461; possesses the property of tinging fluxes, and decomposing phlogisticated alkali.—Is this the acid of tin?

(*a*) See the Treatise on Arsenic.

(*b*) Mr. Scheele, Act. Stockholm, 1778.

This acid, exposed to the flame upon charcoal, is absorbed; in the spoon it emits a white smoke, which, upon contact of the interior cone, grows of a beautiful blue; but, exposed to the exterior cone, again grows white: it tinges microcosmic salt of an elegant green; borax, with a small quantity of it, exhibits an ashen colour by reflection, but by refraction a dark violet. No other acid tinges the fluxes.

The acid of borax, commonly called sedative salt, easily liquefies, and in the same manner, but with far less intumescence than borax: it remains fixed in a pellucid globule (§ VI.).

The acid of tartar is not to be confounded with cream of tartar, which is partly saturated by the vegetable alkali (c): this liquefies upon the first contact of the exterior flame; soon is inflated, foams, grows black, and sends forth a smoke and blue flame, leaving a spongy coal, which soon leaves white ashes of a calcareous nature. In order to observe these changes distinctly, the combustion must be occasioned slowly by the weakest part of the flame.

Crystallized acid of sugar is by the exterior flame first made of an opaque white, then flows, and finally soon flies off, without leaving any residuum.

(c) Act. Stockholm, 1770.

The acid of phosphorus occurs in all the natural kingdoms ; when dried it is easily fused, and assumes the form of a pellucid globule, which yet attracts the moisture of the atmosphere.

§ XI. *Alkalis.*

The crytallized vegetable alkali first becomes opaque, and decrepitates long and violently, then melts into a globule which persists in the spoon, but expands on the charcoal, and is absorbed with a crackling noise.

The mineral alkali has the same properties as the sal sodæ described in § VI.

The volatile alkali liquefies a little, and is dissipated.

§ XII. *Neutral Salts.*

Several of the neutral salts flow twice, but, according to their different natures, exhibit different phænomena ; which a few examples will sufficiently illustrate.

The decrepitating Salts.

These are broken and dispersed by sudden heat : of this sort are vitriolated vegetable and volatile alkali, salited vegetable and mineral alkali.

Volatile

Volatile Salts,

Which have a base totally volatile, and generally fly off; vitriolated, nitrated and salited volatile alkali.

Genuine salt of amber by the exterior flame on the charcoal liquefies and smokes; by the interior takes fire, and in burning disappears with a blue flame. In the spoon the same happens, except when the salt abounds with oil, which almost always happens: in this case some coaly vestiges remain. The spurious salt of amber differs according to the frauds used in its preparation; it generally in the beginning swells, smokes, and grows black, then white; and finally, melts into a fixed white mass.

Detonating Salts.

These salts, which always abound with nitrous acid, liquefy in the spoon, and persist even on the charcoal, unless it takes fire; for when ignited they immediately take fire on the contact of phlogiston, sending forth a violent flame, with a detonating noise. During this operation the acid is dissipated, and the basis, if fixed, remains alone. If the base be volatile, scarce any detonation is excited, for the salt flies totally off.

Nitrated vegetable alkali shews a blue flame, but the nitrated mineral and volatile alkali a yellow ore.

Carbo-

Carbonaceous Salts.

These, by the combustion of their acid, yield spongy coals, which, when ignited, soon grow white, leaving behind the alkaline base; such are acid of tartar, crude tartar, sal acetosellæ, and tartarized vegetable and mineral alkali.

Hepatiscent Salts.

These, exposed to the flame on the charcoal, flow, and yield a yellow or red mass, which diffuses an hepatic smell, especially when moistened by any acid. To this class belong all those fixed in the fire, containing vitriolic acid, which, when saturated with the phlogiston of the charcoal, generate sulphur; these are vitriolated vegetable and mineral alkali.

§ XIII. *Middle earthy Salts.*

Of the middle earthy salts few flow so perfectly as to be reduced to a globule, nor do they all fuse actually, though the water of crystallization in its departure excites a foam: those which contain vitriolic acid effervesce violently with borax and microcosmic salt, but are difficultly dissolved by sal sodæ.

Decrepitating Salts.

Gypsum spathosum.

Intumescent

Intumescent Salts.

Vitriolated magnesia swells, foams, and, when repeatedly exposed to the flame, may be fused.

Alum is somewhat different; for, finally, all ebullition ceases, and the mass remains immoveably at rest, and it undergoes no other change than to split: when hot it is variegated with blue spots.

Acetated lime swells much like alum, but scarcely adheres to the charcoal.

Nitrated magnesia swells with a crackling noise, but without any detonation.

Salited magnesia in a dry state belongs to this class.

Fusible Salts.

Although gypsum eluded the force of fire in Pott's furnace, yet it may be fused in a moment, if a section of the lamella be exposed to the blue flame: though naturally pellucid, it instantly acquires an opacity — the water goes off without ebullition.

Carbonaceous Salts.

Tartarized lime and magnesia; nay, all the earths united with acid of tartar.

Soluble in Borax and Microcosmic Salt, with Effervescence.

Lime, magnesia, vitriolated clay, and acetated lime.

§ XIV. Mid-

§ XIV. *Middle metallic Salts.*

Some of the middle metallie salts, either containing a large quantity of water, or retaining pertinaciously the acid, flow in the fire, others only foam: most of them recover, at least partly, their metallic appearance, especially when they touch the coal, leaving at the same time a shapeless scoria. By the addition of borax the scorix are dissolved and the regulus better collected, but here we consider the salts alone: the fluxes are tinged in the same way as by the metallic calxes, § XXII. XXXV.

Decrepitating metallic Salts.

Nitrated lead, tartarized antimony.

Volatile metallic Salts.

To this belong the salts whose base is mercury, as they are dissipated by fire; those which contain marine acid in general fly off more quickly than those which are loaded by any other menstruum.

Detonating metallic Salts.

Silver, mercury, lead, and bismuth, united with nitrous acid.

Intu-

Intumescent metallic Salts.

At the first approach of fire they swell with noise, and a certain ebullition, but then remain immoveable; vitriolated and nitrated copper, iron and cobalt vitriolated, vitriolated and nitrated zinc.

Fusible metallic Salts.

These are, by the exterior flame, easily reduced to globules. By this method silver and lead salited in the spoon put on the horny appearance, but by a long violent fusion they again put it off, the acid being too much diminished: hence it appears with what caution these metals are to be made horny in the crucible.

Silver and lead vitriolated, copper and zinc salited.

Carbonaceous metallic Salt.

Tartarized antimony.

Metallic Salts tinging the Flame.

Vitriolated copper, and also nitrated copper, produces a greenness; but salited copper acts with far more efficacy. The green crystals of this first grow red by the exterior flame; they soon liquefy, and grow black; they make the flame at first of a deep blue, which afterwards verges to a green. The
flame

flame thus tinged expands much, and remains so until the whole mass of the salt is dissipated: this green salt, added to microcosmic salt in fusion, immediately shews a beautiful flame; the clear globule is tinged green, and does not grow opaque or brown, unless a large quantity of the microcosmic salt be added; a circumstance which takes place much sooner upon the addition of a smaller quantity of borax.

§ xv. *Different Species of Earths.*

Earths are in general either simple (which I call *primitive*) and incapable of decomposition or mutual transmutation by any means hitherto known—of these five only have been as yet discovered—whether a sixth exists in the diamond we are ignorant.

Those are called *derivative* which arise from a mixture of two or more of the primitives. Many of those which Mr. Cronstedt thought to be simple, I have discovered, by the humid analysis properly conducted, to be compound; this is not to be objected to that great mineralogist, as the chemical art at his time had not investigated the treasures of the mineral kingdom.

§ xvi. *Habitudes of the primitive Earths.*

Lime.

This (which by itself is infusible) by a sufficient degree of heat loses its property of

effervescing in acids ; it acquires solubility in water, the power of generating heat with it, and of suffering spontaneous calcination. These last properties however it loses, if too much urged by heat. The heat it generates with water may easily be tried by a drop of water on the back of the hand, with the addition of a small piece of lime just cooled after burning.

Crude calcareous earth effervesces a little with mineral alkali, and is divided into small particles but sparingly dissolved ; when overburned it seems not to be divided or diminished.

In borax the former dissolves with effervescence, the latter scarcely generates any bubbles.

In microcosmic salt the same phenomena appear, but the effervescence is somewhat greater.

It is also observable that a very small piece of calcareous earth is easily dissolved in borax and microcosmic salt, yielding sphaerules altogether pellucid ; but if more earth be gradually added, the flux, at length saturated, retains the dissolved matter, indeed, while in perfect fusion ; but on removing the flame, the part which was taken up by means of the heat alone, separates ; from hence clouds arise at first, and the whole globule becomes opaque, and recovers its transparency again by fusion. This is entirely correspondent to what happens in the humid

humid way : for warm water, saturated with nitre, or Glauber's salt, upon cooling is obliged to deposit that part which it had taken up in virtue of its warmth. If the fused pellucid globule (which would grow opaque upon cooling) be quickly plunged into melting tallow, water, or other substance, hot (for cold generally cracks it) so as to grow suddenly hard, it retains its transparency, the particles being as it were fixed in that state which is necessary to transparency. This is a phenomenon highly worthy of observation, which cannot be seen in the crucible.

Terra Ponderosa.

Terra ponderosa, exposed alone to the flame, becomes, like calcareous earth, caustic, soluble in water, and non-effervescent in acids.

In sal sodæ it effervesces only a little, but is sensibly diminished.

In borax it dissolves with slight effervescence.

As also in microcosmic salt; but here it effervesces somewhat more violently.

The phenomena observed on saturation with calcareous earth, have place here also.

Magnesia, ignited alone, loses its aerial acid, together with the property of effervescing in acids.

In sal sodæ it effervesces a little, but is scarcely diminished.

In borax it dissolves with a slight effervescence.

As also in microcosmic salt, but with a more violent motion.

Clay.

Common argillaceous earth abounds with heterogeneous particles, and always contains a considerable quantity of siliceous earth, at least, which generally amounts to half; hence, when clay is required pure, as in this instance, the earth of alum, digested in an alkaline lixivium, and well washed, must be employed.

Exposed to the flame it grows hard, contracts its bulk, but does not fuse.

In sal sodæ it effervesces a little, but is sparingly dissolved.

In borax it dissolves with remarkable effervescence.

In microcosmic salt a still more violent ebullition takes place.

Siliceous Earth.

Alone it is not fused.

Sal sodæ dissolves it with violent effervescence; and if the siliceous earth dissolved exceeds the weight of the flux, it yields a pellucid glass. This, and all the other operations with sal sodæ, must be performed in the spoon.

In borax it dissolves slowly, without any ebullition.

In microcosmic salt very slowly, and without effervescence.

§ XVII. *Derivative Earths.*

To avoid confusion from multiplicity, we shall collect these into classes, according to their most remarkable habits.

Decrepitating.

Spathous mineral fluor.

Lapis ponderosus (*d*).

Calcareous spar. Spathum ponderosum.

The decrepitation may be performed without scattering, in a glass tube closed by the finger, and held over the flame.

Infusible.

Diamond. Pure Asbestos *. Refractory clay *. Hyacinth. Hydrophanous siliceous jasper.

Lapis ponderosus.

Pure mica *.

(*d*) This is the name given by Mr. Cronstedt (§ 209) to a fossil, which he enumerates among the ores of iron, and which possesses a peculiar specific gravity. I have attempted the analysis of this mineral, and have discovered in it lime united to a species of acid hitherto unknown; this acid, if I mistake not, is the radix of some metal. There is also present a portion of iron, which is indeed but seldom wanting in minerals. The specific gravity of this acid, and its habitudes with fluxes, and phlogisticated alkali, indicate its metallic nature;—but we shall elsewhere treat of this matter more at large.

Quartz.

Ruby.

Sapphire. Flint. Steatite *.

Topaz.

Those four marked with a * are indurated by fire.

Infusible, changing Colour.

Bolar earths generally grow black—lime, mixed with aerated magnesia, black; lime, blackened by subtle bitumen, white.

Of the gems some change or lose colour; these are, the chrysolith, topaz, and sometimes the sapphire.

The red and green jasper acquire a whitish or grey colour.

Green, black, and red steatite grow white.

Fusible without Ebullition.

Martial asbestos. Augites (aqua marina*).

Basaltes.

Chrysolith *.

Mineral fluor.

Granite.

Marga.

Petrofilex.

Emerald *.

Spathum ponderosum (this corrodes the charcoal, and acquires an hepatic taste).

Spathum pyromachum.

Trapp.

The earths marked with a * do not, but with

with great difficulty, shew any signs of fusion.

Fusible with Ebullition.

Lithomarga.

Schoerl (e).

Turmalin. The inflated scoria quickly grows white, though the stone is brown.

Zeolith.

Fusible altogether in Sal Sodæ, and with Effervescence.

Achates.

Chalcedony. Cornelian. Cos turcica *.

Mineral fluor *.

Onyx. Opal.

Quartz.

Common flint. Spathum ponderosum.

Those marked (*) effervesce but little.

Divisible with or without Effervescence in Sal Sodæ, but not entirely soluble.

Amianthus. Asbestos.

Basaltes.

Chrysolith * (f).

(e) I use the names *schoerl* and *trapp*, which are now known all through Europe. By *basaltes* I understand larger prisms, which compose the Giant's Causeway, Staffa, and other columnar mountains.

(f) The yellowish crystalline matter which fills up the interstices of the native Siberian iron, exhibits the same properties with respect to fire as the chrysolith.

Garnet *.

Hornblende.

Jasper.

Lapis ponderosus. Lithomarga.

Mica. Matrix of the alum of Tolfa.

Petrofilex.

Aluminous schist. Tegular schist of Hel-
sing. Emerald. Spathum pyromachum,
Steatites.

Talc. Trapp. Trippel. Turmalin.

Not fusible or divisible by Sal Soda.

Diamond.

Hyacinth.

Ruby.

Sapphire.

Topaz.

Soluble in Borax, with more or less Effervescence.

Mineral fluor *.

Marga. Mica *. Ore of Tolfa.

Aluminous schist. Tegular schist of Hel-
sing *.

Spathum ponderosum. Schoerl.

Talc. Turmalin.

Those marked * effervesce but little.

Soluble in Borax, without Effervescence.

Achates. Diamond. Amianthus. Af-
bestos.

Basaltes.

Chalcedony.

Chalcedony. Cornelian. Chrysolith. Cos
turcica.

Garnet.

Hyacinth. Hydrophanous filiceous jas-
per.

Lapis ponderosus. (The flux grows hard-
ly blue ; on too much cooling it becomes
white and opake).

Lithomarga.

Onyx. Opal.

Petrofilex.

Quartz *.

Ruby.

Sapphire. Common flint *. Emerald.

Steatite. Spathum pyromachum.

Trapp. Trippel. Topaz *.

Zeolith.

Those marked * require a greater quan-
tity of flux, and longer heat, than the rest.

*Soluble in Microcosmic Salt, with more or less
Effervescence.*

Basaltes *.

Cos turcica.

Mineral fluor *.

Lapis ponderosus.—It effervesces at first,
then scarcely dissolves: the flux acquires a
fine blue tinge, without any mixture of
redness. The colour is discharged by
the exterior flame, or by a small quan-
tity of nitre, but is restored by the interior
flame; if the proportion of earth be large
it

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it acquires a pellucid brown colour, not dischargeable either by nitre or the flame; if still larger, it grows black and opaque.

Marga. Mica *. Aluminous ore of Tolfa.

Aluminous schist. Tegular schist of Hel-
sing *. Schoerl. Spathum ponderosum.

Turmalin*.

Those marked * effervesce but little.

Soluble in Microcosmic Salt, without Effervescence.

Agate. Diamond. Amianthus. Asbestos.

Chalcedony *. Cornelian *. Crysolith *. Granite.

Hornblende. Hyacinth. Hydrophanous siliceous jasper*.

Lithomarga.

Onyx *. Opal*.

Petrofilex.

Quartz*.

Ruby.

Sapphire. Common flint. Emerald. Steatites.

Spathum pyromachum.

Talc. Topaz. Trapp. Trippel.

Zeolith.

Those marked * are more difficultly dissolved than the rest, and scarce sensibly.

In general it is to be observed, 1st, that when the effervescence is to be examined, only a very small piece of the matter is to be added to the flux, as the most subtile powder contains air, which, being expelled by the heat, forms the appearance of effervescence. 2d, That the solution is often accelerated by lime, spathum ponderosum, gypsum, and other additaments, both in borax and microcosmic salt. 3d, That gypsum alone is sometimes an excellent and very useful flux. This salt, with an equal portion of fluor mineral, is easily reduced to a pellucid globule, which yet, upon cooling, grows white and opaque. The spathum ponderosum also unites with mineral fluor, but the mass does not become pellucid.

§ XVIII. *Different Species of inflammable Substances.*

The whole theory of inflammation depends upon that subtile principle which goes by the name of phlogiston; but this, so far as is yet known, can never be collected pure and alone, but always requires a suitable base, to which it must be connected, in order to become manageable. Scarce any body exists entirely destitute of it, but a certain accumulation of it is necessary for deflagration; this accumulation takes place in spirit of wine, in oils, in sulphur, in zinc,

zinc, arsenic, and perhaps in tin. It is also necessary that its connection shall be so loose, that the circumambient pure air may dissolve the union.

The dry inflammable substances, which alone are here to be considered, are of two kinds; viz. either coagulated and indurated oils, which are commonly called bitumens, or an acid saturated with phlogiston, such as sulphur. Some of the bitumens are pure, such as asphaltus, ambergris, and amber; others residing in a copious earthy base: hence we have mountain pitch, bituminous schists, and lithanthraces.

Vitriolic sulphur is seldom found alone: it readily unites with other matters, especially metals; and hence result mineralizations, which belong the more expressly to metals, as it is certain that they are very seldom inflammable.

§ XIX. *Habitudes of inflammable Substances in the Fire.*

Most of the inflammable substances, when exposed to the apex of the flame, begin to liquefy, unless entangled in much earth, which yet does not always prevent their inflammation: when they are once inflamed let the blast be stopped until they have burned away, either alone or with a flux; and the residuum, if any, be examined afterwards by the flame.

Ambergris

Ambergris burns with a white odoriferous and smoky flame; when very pure it is totally consumed by degrees, but when impure it is extinguished, leaving behind a black mass, which soon grows white by ignition, and consists partly of a calcareous powder.

Transparent amber exhibits almost the same habits, but by heat in the spoon it vanishes totally; so that this way we can hardly form any judgment concerning a residuum, which yet is easily obtained from opaque amber.

Pure asphaltus burns with a smoke, and is totally consumed, without any residuum.

Mountain pitch leaves black scorix, shining and brittle.

Bituminous schist and lithanthraces, besides their matrix, leave an oily coal, or even spongy scorix, if the residuum liquifies at all.

Common sulphur readily fuses alone, and grows red; it takes fire, and is consumed with a blue flame, and a most penetrating suffocating odour.

Molybdæna contains a portion of common sulphur united to a peculiar (g) acid. This does not take fire, and upon the charcoal suffers little change; but, exposed to the flame in the spoon, it deposits a white smoke

(g) Mr Scheele, Act Stockholm, 1777.

in the direction of the blast; this smoke, by the contact of the interior cone, grows blue, but loses its colour by the exterior cone: it is scarcely changed by borax and microcosmic salt, but dissolves in sal sodæ with violent effervescence; on fusion it grows red and transparent; on cooling, dilutely red and opake, and has an hepatic smell.

Plumbago, another species of sulphur, contains aerial acid loaded with phlogiston (*b*); on burning it smokes, but the smoke is only seen at the instant the flame ceases. It differs from molybdæna in this, that it deposits no white powder, and particularly in not being taken up by sal sodæ; it is not changed by borax or microcosmic salt.

The ores which are called inflammable, take fire difficultly; some of them are scarcely changed, others are consumed or fly off, leaving the metallic calx behind.

In general the fluxes are tinged by phlogiston; but unless this volatile principle be fixed by some metallic calx, the tinge is easily destroyed by burning.

(*b*) Mr. Scheele, Act Stockholm, 1777.

§ xx. *Different Forms under which Metals appear.*

The metals are distinguishable from all other substances by their peculiar splendor and superior specific gravity: they occur in the bosom of the earth in three different states, either altogether in a metallic form, in which case they are called *native*; or simply deprived of phlogiston, and resembling earths, when they are denominated *calciform*; or, finally, dissolved by sulphur or acids, on which occasion they take the appellation of *mineralized*. Each of these forms shall be separately considered.

§ xxi. *Various Habits of Metals in the Fire.*

The metals exposed to the flame do not all shew the same habits.

The perfect metals do not, even in the most intense heat, lose a sensible quantity of their phlogiston; and when calcined in the humid way recover their former nature simply by fusion.

The imperfect metals are calcined by fire, especially by the exterior flame, and then, in order to being reduced, indispensably require the contact of a phlogistic substance.

With respect to fusibility, mercury forms one extreme, as it fuses in the ordinary tempe-

temperature of the atmosphere, it cannot therefore be hardened but by artificial cold, and is always in fusion, always fluid; the rest follow in this order: tin, bismuth, lead, zinc, antimony, silver, gold, arsenic, cobalt, nickel, iron, manganese, and finally platina, which forms the other extreme, as it scarcely fuses but in the focus of a burning mirror; all these, the two last excepted, yield to the blow-pipe without any additament. Forged iron indeed is not melted without difficulty, but fused iron perfectly.

With respect to fixity, some fly off altogether, others are partly and slowly resolved into smoke.

Metals in fusion affect a globular form, and therefore easily roll off the charcoal, especially if they are of the size of a grain of pepper; therefore, either smaller pieces should be used, or they should be placed in excavations made in the surface of the charcoal. On first fusing they assume a polished surface, an appearance which the perfect metals always retain: but the imperfect are soon obscured by a calcined pellicle; for the surrounding air attracts the phlogiston with great avidity, especially when assisted by heat, which yet alone is not able to expel that principle.

The colours communicated to the calxes by fire vary.

Some of the calxes easily recover their metallic form simply by exposure to flame upon

upon the charcoal; others are reduced in this way with difficulty, and some not at all.

The reduced calxes of the volatile metals immediately fly off.

In the spoon they exhibit nitrous globules, but it is very difficult to prevent them from being first dissipated by the blast.

With Fluxes.

The metals are taken up by the fluxes; but as sal sodæ yields an opaque sphærule, we neglect it.

Globules of borax, upon the addition of any metallic calx, dissolve and fuse it, and, unless too much loaded, appear coloured and pellucid. A piece of metal calcined in the flux produces the same effect, but more slowly.

A portion of the calx generally recovers its metallic form, and floats upon the surface, like one or more excrescences.

In proportion as the globule is more loaded, it more readily spreads upon the charcoal, and at length cannot be formed into a globule; for the metallic additament increases the attraction for phlogiston.

The calxes of the perfect metals are reduced by borax in the spoon, and adhere to it at the point of contact, and there only.

The microcosmic salt acts like borax, but does not reduce the metals; it attacks them more powerfully on account of its acid na-

ture; at the same time it preserves the spherical form, and is consequently adapted in a peculiar manner for the examination of metals.

The tinge communicated to the flux frequently varies, being different in the fused and the cooled globule, and that in a double and altogether different manner; for some of the dissolved calxes, while fused, shew no colour, but acquire one on cooling; others, in the state of fluidity, have a much more intense colour. If too great a concentration of colour injures the transparency, the globule, on compressing it with the forceps, or drawing it out into a thread, will exhibit a thin and transparent mass; but if the opacity arises from supersaturation, this artifice will not serve, but more flux must be added. No metal, unless calcined, communicates a tinge. As the fluxes attract the metals with unequal forces, these last precipitate one another.

Metals, mineralized by acids, possess the properties of metallic salts; and those loaded with aerial acid that of calxes, as this subtilè menstruum is easily expelled without any effervescence; but when loaded with sulphur they possess properties of a peculiar kind. They may be fused, nay calcined, upon the charcoal, as also in a golden or well-gilded silver spoon. The volatile are distinguishable by the smell or smoke, the fixed residua, by the particles reduced or precipitated

precipitated upon iron, or from the tinge of the fluxes. We shall now examine the more simple cases, and treat of the more complex in another Work (*b*).

§ XXII. *Gold in a reguline State.*

Reguline gold fuses upon the charcoal, and is the only one which remains unchanged.

Calcined.

That gold may be deprived of its phlogiston in the humid way, has been already shewn; this calx may be reduced by fire alone (§ XXI.); but that this calcination may also be effected by fire is seen from the ruby-coloured glass, which may be made, even by the blow-pipe, in the following way:

To a globule of microcosmic salt let there be added a small piece of solid gold, of gold leaf, of purple mineral, or (which is best) of the crystalline salt formed by a solution of gold in aqua regia in which sea-salt is contained; let this be again fused, and added, while yet soft, to turpeth mineral, which immediately grows red on the warm contact. The fusion being afterwards repeated, a vehement effervescence arises; when this is considerably diminished let the blast be stopped for a few

(*b*) *Sciagraphia Regni Mineralis.*

moments, again begun, and so continued, until almost all the bubbles disappear. After this sometimes the sphærule, on cooling, assumes a ruby colour; but if this does not happen, let it be just made soft by the exterior flame, and upon hardening this tinge generally appears. If the process should fail at first, owing to minute circumstances which cannot be described, it will succeed on the second or third trial. The ruby-coloured globule, if compressed by the forceps while soft, often becomes blue; by sudden fusion it generally assumes an opal colour, which by refraction appears blue; by reflection, a brown red: but if further urged by the fire it loses all colour, and appears like water; yet the redness may be re-produced several times, by the addition of turpeth mineral.

In the same way the flux is reddened by calx of tin, in the place of the turpeth; but it has a yellowish hue, and, besides, more easily contracts opacity. The redness communicated by turpeth mineral is of a purple sort, altogether like that of a ruby.

Borax produces the same phenomena, but more rarely. It must also be observed, that the slightest variation in the management of the fires often makes this experiment fail.

As the ruby colour may also be produced by copper (§ XXVII.), a doubt may arise, whether it be the gold, or the remains of the copper (which cannot be completely separated either by antimony or nitre) which in
this

this case produces the red colour : but it is not improbable that both metals may occasion the same colour ; besides, copper is often found to contain gold.

Mineralized Gold.

Gold cannot be directly united with sulphur ; but by means of iron, which attracts both strongly, they are sometimes found united into a golden pyrites : but as the quantity of gold is very small, a visible globule can scarcely be extracted by fusion and scorification by the blow-pipe.

I have as yet had an opportunity of examining the ore of Nagyay only imperfectly :—upon the charcoal it smokes a little, liquefies, and finally yields a white globule, bright like silver, and malleable ;—a yellow cloud is observed about it. Borax takes it up without effervescence or tinge ; but microcosmic salt, with effervescence, and of a brownish red ; but by long fusion the tinge is discharged, and cannot be brought back, either by the exterior flame or nitre. A metallic globule like the former floats in the flux.

§ XXIII. *Platina.*

Native grains of platina do not at all yield to our fire, either alone or mixed with fluxes, which yet it often tinges of a green colour ;

but platina, precipitated from aqua regia by vegetable or volatile alkali, is reduced by microcosmic salt to a small malleable globe; seven or eight of these, flattened by the hammer, I have been able to bring together to a malleable mass; but more only yielded a brittle one. Platina scarcely loses all its iron, unless reduced to very thin fusion; hence it easily appears how difficult the depuration of a large mass must be.

§ XXIV. *Silver, reguline.*

Reguline silver easily liquefies, and resists calcination.

Silver-leaf, fastened to a thin glass by means of the breath, or a solution of borax, may easily be fixed on it by the flame, and, what is remarkable, through the glass it appears of a gold colour; but care must be taken not to crack the glass.

Calcined Silver.

Calcined silver, precipitated from nitrous acid by fixed alkali, is easily reduced.

The microcosmic salt dissolves it quickly and copiously, but upon cooling it grows opaque, of a whitish yellow, which is also sometimes the case with leaf-silver; if copper be present it is discovered by a green colour, and sometimes by a ruby tinge, unless

less we rather chuse to impute that to gold. The globules can scarcely be got pellucid, except the quantity of calx be very small, but with borax a longer fusion is necessary to obtain an opacity.

The globule loaded with dissolved silver, during fusion in the spoon, covers a piece of copper added to it with silver, and becomes itself of a pellucid green; antimony speedily takes away the milky opacity of dissolved luna cornea, and separates the silver in distinct grains. Cobalt, and most of the other metals, also precipitate silver in the same way as by the humid method; i. e. a double elective attraction takes place. The metal to be dissolved remains untouched so long as it retains all its phlogiston; but is taken up when a sufficient quantity of that principle has shifted to the precipitate, and reduced it.

Mineralized Silver.

Silver, mineralized by marine and vitriolic acid, yields a natural luna cornea, which upon the charcoal produces a number of small metallic globules: it dissolves in microcosmic salt, and renders it opake: it is reduced, at least partially, by borax.

Sulphurated silver (the glassy ore of silver) fused upon the charcoal, easily parts with the mineralizing substance; so that a polished globule is often produced, which, if necessary, may be depurated by borax: the

silver may also be precipitated by the addition of copper, iron, or manganese.

If arsenic be also present (as in the red ore of silver) it must be first freed from the sulphur by gentle roasting; and finally entirely depurated by borax: it decrepitates at first.

Copper, together with sulphur and arsenic, mixed with silver (the white ore of silver) yields a regulus containing the same alloy.

Lead, loaded with sulphur and silver (galena) is to be freed in the same way from the sulphur, after which the lead is gradually dissipated by alternately fusing and cooling, or is separated in a cupel from the silver, by means of flame. In galena I have not yet been able to precipitate the silver distinct from the lead, but the whole mass becomes malleable: the same is true of tin, but the mass is more brittle.

§ xxv. *Mercury.*

Pure mercury upon the charcoal flies off by a moderate heat, the fixed heterogeneous matters (if any there be) remaining behind.

When calcined it is easily reduced and dissipated: the fluxes take it up with effervescence, but it is soon all driven off.

I have never yet had an opportunity of examining mercury, naturally mineralized by acids, but this is undoubtedly volatile.

When

When loaded with sulphur it liquefies upon the charcoal, shews a blue flame, smokes, and gradually disappears; but if cinnabar be exposed to the blow-pipe upon polished copper, the mercurial globules are fixed all around.

§ xxv. *Lead, reguline and calcined.*

As the imperfect metals are easily calcined, we shall consider lead under the two forms, *viz.* reguline and calcined.

Lead readily fuses, and continues for some time to retain a metallic splendor; by a more intense heat it boils and smokes; hence a yellow circle is formed upon the charcoal. It communicates a scarce visible yellow colour to fluxes; and when the quantity is large, the globule, on cooling, contracts a white opacity more or less perfect: when dissolved it is not precipitated by copper. The metals do not precipitate it from sulphur in the same order as from acids.

Lead united to aerial acid, on the first touch of the flame grows red; when the heat is increased it flows, and is reduced to numberless minute globules. When united with phosphoric acid it fuses, and yields an opaque globule, but is not reduced. With fluxes it shews the same habits as calx of lead.

Mineralized Lead.

Sulphurated lead (galena) easily liquefies,
and,

and, being gradually deprived of the volatile part, yields a distinct regulus, unless too much loaded with iron. It may be precipitated by iron and copper.

§ XXVI. *Copper, reguline and calcined.*

A small piece of copper, either solid or foliated, sometimes communicates a ruby colour to fluxes, especially when assisted by tin or turpeth mineral (§ XII.) : if the copper be a little more or a little further calcined, it produces a green pellucid globule, the tinge of which grows weaker by cooling, and even verges to a blue. By long fusion with borax on the charcoal (but hardly in the spoon) all the colour is at length destroyed, and can scarcely be reproduced by nitre, but this colour remains fixed with microcosmic salt. If the calx, or metal to be calcined, during fusion is added in considerable quantity, upon cooling it acquires an opaque red, although, while fused, it is pellucid and green; by a still larger quantity it contracts opacity, even while in fusion, and upon cooling a metallic splendor. Vestiges of copper, so faint as scarcely to tinge the flux, precipitate a visible pellicle upon a piece of polished iron added to it during strong fusion, and the globule in its turn takes the colour of iron : in this way the smallest portions of copper may be discovered.

The

The globule made green by copper, fused in the spoon with a small piece of tin, until the colour is discharged, yields a sphærule of tin, mixed with copper, very hard and brittle: in this case the precipitated metal pervades the whole of the mass, and does not adhere to the surface.

Cobalt precipitates the calx of copper, dissolved in the spoon by flux, in a metallic form, and imparts its own colour to glass, which nickel cannot do. Zinc also precipitates it separately, and rarely upon its own surface, as its fusion can scarcely be avoided.

Mineralized Copper.

Copper loaded with aerial acid, at the first touch of the flame grows black, and fuses in the spoon: on the charcoal the lower part, which touches the ignited support, is reduced.

When loaded with a superabundance of marine acid it tinges the flame (§ xiv.); but with a small quantity it shews in that way no appearance of the metal. Thus the beautiful crystals of Saxony, which are cubic and of a deep green, do not tinge the flame; they impart to microcosmic salt a pellucid greenness. I could not obtain with that salt an opaque redness, although this colour is easily produced in a globule of borax.

Copper simply sulphurated (ashen ore of copper) when cautiously and gently roasted
by

by the exterior flame, finally by fusion yields a regulus surrounded by a sulphurated crust ; the mass, roasted with borax, separates the regulus more quickly.

When iron is present, but in small quantity, the piece to be examined must be first roasted ; let it then be dissolved in borax, and tin added to precipitate the copper. The regulus may also be obtained by sufficient calcination and fusion, even without a precipitant, unless the ore be very poor.

When pyrites contain copper, though less than 0,01 of their weight, yet its presence may be detected by these experiments in small ; let a grain, the size of a flax seed, be roasted, but not so much as to expel all the sulphur ; let it be then well dissolved by borax, a polished rod of iron added, and the fusion continued until the surface, when cooled, loses all splendor. So much borax is required as will be sufficient to make the whole of the size of a grain of hemp-seed. Slowness of fusion is injurious, and by too great tenuity the precipitation is retarded ; this may be corrected by the addition of a little lime : too much calcination is inconvenient, for by this the globule forms slowly, is somewhat spread, becomes knotty when warm, corrodes the charcoal, destroys the iron, and the copper does not precipitate distinctly ;—this defect is amended by a small portion of the crude ore.

When

When the globule is properly fused, as directed, immediately upon stopping the flame let it be thrown into cold water, in order to break suddenly: if the cupreous content be less than 0,01, one end of the wire only is covered with copper, which otherwise would be entirely covered.

The celebrated Gahn, who has examined copper ores with peculiar accuracy, has another method of discovering the smaller traces of that metal; namely, a grain of the ore, well freed from sulphur by calcination, is exposed to the action of the flame, driven suddenly upon it, *per vices*; and at these instants a cupreous splendor appears upon the surface, which otherwise is black; and this splendor is the more quickly produced, in proportion as the ore is poorer.

Cupreous pyrites on roasting tinges the flame green.

§ XXVII. *Iron, reguline and calcined.*

Forged iron is calcined, but can scarcely be fused, and when fused liquefies.

Forged iron cannot be fused by borax; it fuses in microcosmic salt, but is rendered brittle.

Calcined iron, by heating on the charcoal, becomes magnetic—in the spoon it fuses.

The fluxes grow green with this metal; but in proportion as the phlogiston is more
I deficient

deficient they grow more of a brownish yellow: on cooling the tinge is much weakened; nay, when originally weak, entirely vanishes. By too much saturation the globule becomes black and opaque.

The sulphureous pyrites may be collected into a globule by fusion, and is first surrounded by a blue flame; but as the metal is easily calcined, and changes into black scoriae, neither by itself, nor with fluxes, does it exhibit a regulus;—on roasting it grows red.

§ XXVIII. *Tin, reguline and calcined.*

Tin easily liquefies, and is calcined.

The fluxes dissolve the calx sparingly, and, when saturated, contract a milky opacity. Some slight vestiges of this metal, dissolved in any flux, may be distinctly precipitated upon iron.

Crystallized ore of tin, urged by fire upon the charcoal, yields its metal reduced.

§ XXIX. *Bismuth, reguline and calcined.*

Bismuth has nearly the same habits as lead; the calx is reduced upon the coal, it is fused in the spoon.

The calx, dissolved in microcosmic salt, yields a brownish yellow globule, which
grows

grows more pale upon cooling, at the same time losing some of its transparency: by too much calx-a perfect opacity is produced.

A similar mass is obtained with borax in the spoon; but on the coal a grey one, which can scarcely be freed from bubbles. On fusion, the glass smokes, and forms a cloud about it.

Bismuth is easily precipitated by copper and iron.

Mineralized Bismuth.

Sulphurated bismuth is easily fused, exhibiting a blue flame and a sulphureous smell. Cobalt, when added, by means of the sulphur, enters the globule; but the scoria soon swells into distinct partitions, which, further urged by fire, exudes globules of bismuth.

Sulphurated bismuth, by the addition of borax, may be distinctly precipitated by iron or manganese.

§ xxx. *Nickel, reguline and calcined.*

The regulus of nickel fused is indeed calcined, but more slowly than other metals.

The calx imparts to fluxes an hyacinthine colour, which on cooling grows yellow,

and by long-continued fire may be destroyed; if the calx of nickel is contaminated by ochre of iron, the latter is first dissolved. Nickel dissolved is precipitated on iron, nay on copper—an evident proof that it does not originate from either of these metals.

Mineralized Nickel.

Sulphurated nickel is nowhere found without iron and arsenic: the regulus is obtained by roasting, and fusing with borax, though it still remains mixed with some other metals.

§ XXXI. *Arsenic, reguline and calcined.*

Regulus of arsenic kindles by a sudden heat, and not only deposits a white smoke on the charcoal, but diffuses the same copiously all around. The calx smokes with a garlic odour, but cannot burn.

By a proper quantity the fluxes grow yellow, without opacity; and by a long-continued fire the volatile additament is dispelled. Iron and copper precipitate this semi-metal under a metallic form, which gold is not able to do.

Yellow arsenic liquefies, smokes, and totally flies off: when heated by the exterior flame, so as neither to liquefy nor smoke, it grows red, and again, upon cooling,

ing, yellow; if it only begins to fuse, it acquires a red colour, which remains after cooling. Realgar liquefies more easily, and is besides totally dissipated.

§ XXXII. *Cobalt, reguline and calcined.*

The regulus of cobalt fuses, and may partly be depurated by borax, for the iron is first calcined and taken up. The smallest portion of the calx tinges the flux of a deep blue, which yet, when seen by refraction, appears violet: this colour is very pertinacious in the fire. Cobalt is precipitated upon iron from the blue globule, but not upon copper.

When calx of iron is mixed with that of cobalt in a flux, the former is dissolved.

Mineralized Cobalt.

Cobalt, in fusion, takes up about one third of its own weight of sulphur, but then assumes so refractory a nature, that it can scarcely be fused. Iron, copper, and several other metals, precipitate cobalt.

The common ore, by roasting and fusion, yields a regulus, though an impure one.

The green cobalt, which I have hitherto examined, tinges the microcosmic salt indeed of a blue, but at the same time shews red spots indicating copper.

egit but sulphur to them (charcoal) and tinge
 cloud a glistening, and the flame more or less, depositing a cloud
 which is white. *Zinc, reguline and calcined.* It
 have no matrix are tinged by those which

Fused zinc takes fire, sending forth a lan-
 uginous white calx, which soon extin-
 guishes the beautiful bluish green flame;
 but if the reguline nucleus, included in this
 lanuginous matter, be urged by the fire, it is
 inflamed now and then, but flies about, and
 as it were explodes.

When added to borax, it excites a spu-
 mescence, and at first tinges the flame; it
 continually diminishes, and the flux spreads
 upon the charcoal: but in fused microcos-
 mic salt it not only occasions spumescence,
 but sends forth several flashes, with a crack-
 ling noise. By too great heat it explodes,
 sending forth ignited particles.

The white calx, exposed to the flame on
 the charcoal, puts on a yellowish splendor,
 which, when the flame ceases, vanishes—it
 remains fixed and refractory. The fluxes are
 scarcely tinged, but when saturated by fusion,
 on cooling grow opake and white. Around
 the globules clouds appear, which are of a
 nature similar to that of the metallic calx.

Dissolved zinc is not precipitated by any
 other metal.

That zinc which contains aerial acid has
 the same properties as calcined zinc.

In the pseudo galena sulphur is present by
 means of iron. These in general (upon the
 charcoal)

charcoal) smell of sulphur, fuse, and tinge the flame more or less, depositing a cloud all around. The fluxes dissolve; those which have no matrix are tinged by those which contain iron, and by saturation acquire a white opacity, which verges to brown or black, according to the variety of composition.

§ xxxiv. *Antimony, reguline and calcined.*

Regulus of antimony, fused, and ignited upon the charcoal, affords a beautiful object; for if the blast of air be suddenly stopped, a white smoke rises copiously and perpendicularly, while in the mean time the inferior part round the globule is condensed into crystalline spiculæ, analogous to those which are commonly called argentine flowers.

The calx tinges fluxes of an hyacinthine colour, but on fusion smokes, and is easily dissipated, especially on the charcoal; yet it also there deposits a cloud.

The dissolved metal may be precipitated by iron and copper, but not by gold.

Mineralized Antimony.

Crude antimony liquefies upon the charcoal, spreads, smokes, penetrates it, and in conclusion disappears totally, except a ring which it leaves behind.

§ xxxv. *Manganese, reguline and calcined.*

The regulus of manganese scarcely yields to the flame; for a small particle is easily calcined, and a large one cannot be made sufficiently hot.

The black calx imparts a bluish red colour to the fluxes; the tinge of borax, unless well saturated, is more yellow. The colour may be gradually altogether destroyed by the interior flame, and again re-produced by a small particle of nitre, or the exterior flame alone; these changes may be alternated *ad libitum*.—The cause of this is elsewhere explained.

When loaded with aerial acid it is of a white colour, which by ignition is soon changed to a black.—In other respects this shews the same phenomena as the black calx.

§ xxxvi. *Conclusion.*

From what has been said I think it apparent, that the blow-pipe is an instrument extremely useful, nay necessary, to chemists; for many experiments are daily neglected, 1st, Because they require furnaces, and a large apparatus of vessels;—yet many of these may easily be performed by means of the apparatus above described: 2^d, From the want of time necessary for examining in the ordinary

ordinary way ;—whereas the experiments above mentioned may be finished in a few minutes : 3d, The usual method of examination requires a certain quantity of the matter to be examined, which prevents the examination of such as are scarce or dear ;—but in our way the smallest particle is sufficient.

However, the conveniencies now described, though of great weight, are attended with this defect, that they do not determine the proportions, or at least point them out but very inaccurately, and therefore are not to be preferred to the larger trials, unless when time or other circumstances prevent them. But the first enquiry to be made is, what a substance contains, not how much ; and I have learned, by the experience of many years, that these trials in small suggest the proper method of instituting experiments at large. These experiments have besides some advantages over those conducted in crucibles, *viz.* we can see all the phænomena from beginning to end, which wonderfully illustrates the series of operations, and their causes (§ XXI. xxx.—xxxv.). Experiments made in crucibles are often fallacious, as the substance of the vessel itself is corroded.—We suppose that lime or magnesia, melted with fixed alkali, are united with it in the way of solution ; but the globule, when well fused in the spoon, by its transparency permits us plainly to see that, except the
filiceous

filiceous part, it is only mechanically mixed (§ xvi.). The most intense degree of heat may in this way be obtained in a few minutes, which is scarcely obtained in many hours in a crucible (§ xiii. xxiii.).

This may be sufficient for the commendation of the blow-pipe;—those who use it will gradually discover more of its valuable properties.

END OF THE SECOND VOLUME.

siliceous part, it is only mechanically mixed (§ xvi.). The most intense degree of heat may in this way be obtained in a few minutes, which is scarcely obtained in many hours in a crucible (§ xiii. xxiii.). This may be sufficient for the commination of the blow-pipe;—those who use it will gradually discover more of its valuable properties.

Fig. 5.

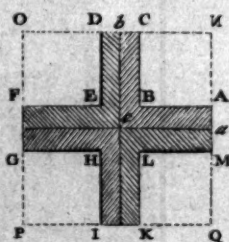


Fig. 3.

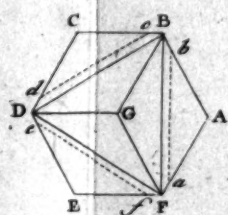


Fig. 6.

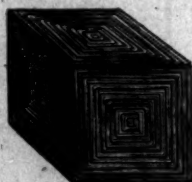


Fig. 4.

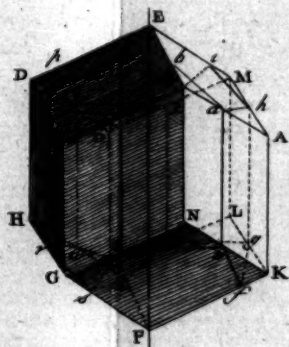


Fig. 12.



Fig. 7.



Fig. 11.



Fig. 8.



Fig. 9.

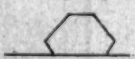


Fig. 10.



Fig. 13.



Fig. 2.

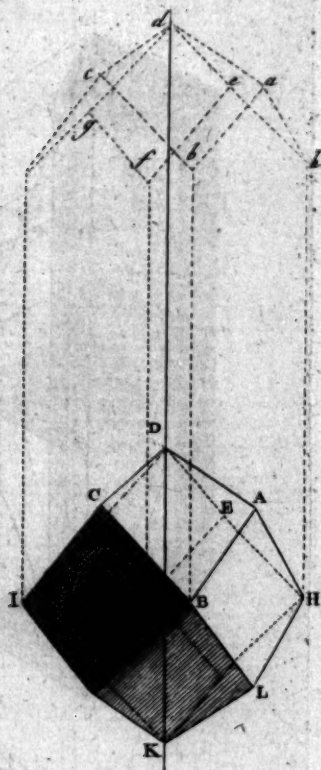


Fig. 1.

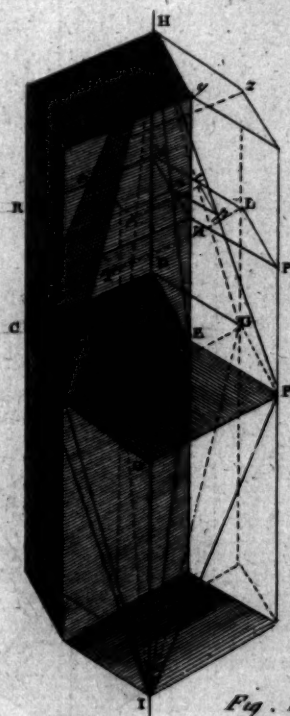


Fig. 15.



Fig. 16.



Fig. 14.



Fig. 17.

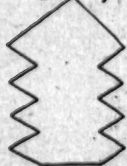


Fig. 19.

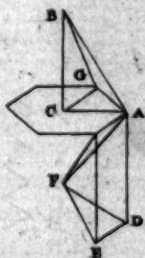


Fig. 18.



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